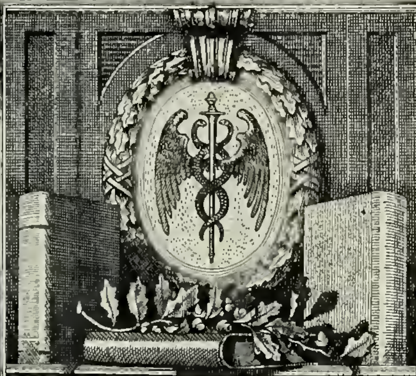

DENTAL ELECTRO-THERAPEUTICS

BY

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SECOND EDITION, THOROUGHLY REVISED

ILLUSTRATED WITH 164 ENGRAVINGS

LEA & FEBIGER
PHILADELPHIA AND NEW YORK
1918

PREFACE TO THE SECOND EDITION.

The kind reception accorded the first edition confirms the opinion expressed in the preface that there is urgent need for literature on dental electro-therapeutics.

This edition has been thoroughly revised and brought up to date with the addition of some new matter and illustrations. The work is specially intended to bring forward the value of electro-sterilization in treatment of root canals and periodontal diseases, and this part has been rewritten with the intention of explaining more fully the technical details of ionization treatment. Details are given in respect to ratio of time required to current strength available in the electro-sterilization of hard and soft oral tissues, and I hope that this will be of value to those who are inexperienced in electrical treatment. I would repeat a word of warning to all who undertake this method of treatment: Do not approach the subject lightly; study carefully sufficient electro-physics to understand the various phenomena of the current with which you are dealing; and obtain a knowledge of the electro-physiological effects; then the therapeutic effects will be most gratifying.

I gratefully acknowledge the assistance given by my friend Dr. C. H. Abbot who has revised the chapter on *x*-ray technic and diagnosis, adding many useful hints to this part of the work. Best thanks are also accorded my daughter Miss Elsie Sturridge, L.D.S., R.C.S. (Eng.), for her valuable assistance in correcting proofs.

E. S.

LONDON, 1918.

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DENTAL ELECTRO-THERAPEUTICS.

PART I.

ELECTRO-PHYSICS.

CHAPTER I.

FRICTIONAL OR STATIC ELECTRICITY.

Theories as to the Nature of Electricity—Electroscope—Leyden Jar—Conduction—Induction—Static Machine.

The study of electrical science embraces a wide and varied field. Many of the phenomena are well known and are placed on sure and scientific footing. Hypotheses have been suggested by eminent modern works in physics which connect electricity with "the ether" in a way comparable with light and heat.

The manifestations of electricity with which we have most to do from a dental aspect are those of energy, force, and power, and in order to understand how these are brought about, and how they can be utilized, the study of electricity should be undertaken from the very primitive forms of electrical phenomena which have been known for ages to the very latest discoveries of the effect of the current from a therapeutic stand-point.

A primitive electrical phenomenon was observed by early workers in the science, who noted that when certain substances are rubbed together a current of electricity is generated which is possessed of certain definite properties.

The character of the current and the effect produced depend on the method of exciting it and the substance used.

From these early experiments in the production of electric current, methods have gradually developed into the present-day elaborate plans for the production of electricity.

It is said that Greek philosophers, many hundred years B.C., noted that when amber was rubbed with cloth it had the power of attracting other bodies, but it was Dr. Gilbert, of Colchester, an Englishman, who in the later part of the sixteenth century, made a study of this phenomenon, and who by experiments determined which bodies would and which would not acquire the property. He also gave the name of Electricity to the cause of this attraction. He tested substances by bringing them near a metal needle, lightly balanced on a pivot.

If we rub a glass rod with silk, or a piece of sealing wax with flannel, the friction will excite electricity in the rubbed end of glass or wax, and if we apply them to some light substances, such as scraps of paper or a suspended pith ball, we shall find that they will attract these bodies.

If we suspend a ball of elder-pith by a silk thread attached to the end of a ruler and apply the piece of silk, which has been used to rub the glass rod, we shall find that the pith ball will be repelled. It is clear that there are two forces excited, the one on the glass rod which attracts, and the other on the silk which repels the pith ball. The substances which have been rubbed have always contained electricity, and although the one attracts and the other repels the pith ball, it is not that there are two kinds of electricity, but only two degrees of the same current; in other words, there is a difference of power or potential. The approach of the glass rod to the pith ball alters the balance of electricity in the ball by inducing a current on the side nearest the rod of opposite sign to that on the rod, the farther side is charged with current of the same sign as that on the rod.

"Bodies charged with unlike electricities attract one another and bodies charged with like electricities repel," or

in the light of recent research, the current from the body which is more highly charged, tends to flow toward that in which there is a deficiency of charge, or away from that in which there is already a charge; in other words, there tends to be a levelling up.

The term positive (+) electricity is applied to current of greater power, and negative (−) electricity to the lesser, the differences are only potential, quantity, direction of flow, and rate of variation of these.

Metals do not become perceptibly electrified when rubbed with other substances in the same way as glass or sealing wax, because they possess the power of conducting electricity; friction fails to disturb the balance of electricity in a substance which so conveys electricity, a good conductor, as it is called, because any disturbance is promptly neutralized by the electricity flowing back to the point from which it was displaced.

Electricity may also pass from one substance in which it has been excited to another which has affinity for it, without actually being brought in contact with it; that is, it may pass through an intervening air space and charge another body, or a currect of opposite sign may be excited in a body brought near a charged body, from which it is insulated. This effect is brought about by induction (see p. 24).

Theories as to the Nature of Electricity.—A theory was propounded by Robert Symmer in 1789 which is generally known as the *two-fluid* theory, in which it is advocated that every body contains an unlimited store of electric fluid of two opposite kinds which neutralize one another, being of equal amounts, the positive and negative kinds. These two electric fluids, he assumed, are capable of being divided, when they are excited by friction or otherwise, and the body which contained the greater amount of fluid is positively electrified, and that which contains the lesser negatively electrified. This hypothesis, which, whether regarded as true or not, possesses an analogous bearing on facts which frequently must be referred to.

Another theory which was suggested by Sir William Watson in 1747, and further elaborated on by Benjamin Franklin, is that there is but one kind of electricity, that when the current is excited or set in motion by friction or otherwise, one body becomes possessed of more current than the other at the expense of the other, the former being positively and the latter negatively electrified. This theory is often referred to as the *one-fluid theory.* Other views on electricity may be obtained from such authors as Green, Stokes, Maxwell, and Oliver Lodge.

The latest theory is that propounded by Prof. J. J. Thomson, of Cambridge, at the beginning of the present century. "According to this, electricity is regarded not as a fluid, but yet as having real existence in the form of minute fragments called *Electrons.* Definite information has been obtained as to the size, etc., of only one kind of electron, that which conveys *negative* electricity. It is possible that positive electrons also exist. These negative electrons can exist alone: when in motion they form an electric current. They can become attached to the atoms of a solid body, and the body is then negatively charged. Each atom of an ordinary solid body is supposed to contain many such negative electrons, paired off with an equal number of positive electrons, and if any of these negative electrons are torn away the body is left positively charged.

"The process by which a metal conducts electricity probably consists in the passing of electrons from one immovable molecule in the solid body to the molecule next to it. The mass of each of these electrons is the same, and only about $\frac{1}{700}$ of that of the lightest atom known (that of hydrogen)." This concise explanation of the electron theory is taken from C E. Ashford's *Electricity and Magnetism.*

The Electroscope.—We have noted that electricity of unlike kinds generated by friction attracts, and that of like kinds repels each other. To tell when a body is electrified, and which kind of electricity it is charged with, the electroscope is an easy means.

There are many forms and modifications of the electroscope. One of the simplest is the gold-leaf electroscope. This consists of a vessel in which is suspended by a metal wire two strips of gold-leaf placed slightly apart. The wire is connected to a brass rod, which passes through the center of the cork in the jar and terminates in a metal plate or knob. If we approach the knob of the electroscope with a glass rod, which has been charged with positive electricity the charge will pass to the gold-leaf, both strips become positively charged and repel each other. Similarly, if a negatively charged substance be applied to the uncharged electroscope, the gold-leaf will be repelled. If the electroscope be affected by a charged body whose sign we desire to determine by bringing in contact an electrified glass rod, if it be positively charged the gold-leaf will diverge still farther, but if negatively charged the gold-leaf will collapse. The glass rod used to test the electroscope will lose none of its electrification, and on removing it the gold-leaf will relapse into its former position.

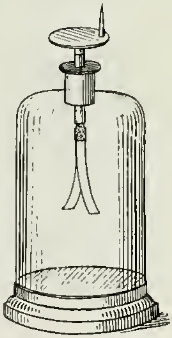


Fig. 1.—Electroscope.

This sensitive instrument will determine if a body is only slightly charged with electricity; if the gold-leaf diverge ever so little the body is charged.

The Leyden Jar.—This is a convenient form of condenser and collector of electricity. It is usually constructed of a glass jar lined with tin-foil on the inside to within a few inches of the top, and similarly coated on the outside. Through the cork is passed a brass rod which terminates externally in a knob, and after going more than half-way into the jar, terminates in a brass chain resting on the metallic lining of the bottom of the jar. The foil lining the inside and coating the outside constitutes the two conductors, the glass intervening, the dielectric of the condenser.

To charge the jar the knob is connected with the conductor of a working frictional machine, and the outer coat is connected with earth, the charge passing to the inner coating of the jar acts on the outer coating through the intervening dielectric by induction. This induced current is conveyed away to earth, leaving a charge of opposite sign held there by the charge on the inner coat. This increases the "capacity" of the inner coat.

FIG. 2.—Leyden jar.

To discharge the jar it is only necessary to bring a conductor which is in contact with the outer coat near to the knob of the jar, when a spark will occur by the coming together of the two electricities, thus establishing equilibrium.

The quantity of electricity which the condenser will contain depends on the surface area of the metallic lining and the strength of the dielectric. If the Leyden jar is made of very thin glass, and a charge of very high potential passed into it, it is liable to be broken by the strain and a spark passes.

The phenomenon of the discharge of the Leyden jar, which takes place with sudden oscillations and a spark, enters into the principle of the construction of many appliances made for electrical treatment. The capacity of the jar varies with the area of the conducting surfaces and the thickness of the dielectric. If the area is large and the dielectric thin, the capacity will be greater than if the dielectric is thick with the same area—that is, the capacity of the jar is greatly increased if the area is increased and the dielectric remains the same thickness.

Conduction.—The conduction of electricity up to a point resembles that of heat, especially when we think of it as being conveyed along a metal. In whatever way an electric current moves it certainly is transferred from point to point by a certain class of substances, which when they permit of the free passing of electricity are known as

conductors, while other substances, which only allow of very little passing or apparently no passing of current are called non-conductors. If the gold-leaf of the electroscope be suspended by glass or vulcanite or some such substance known as a non-conductor, no current would pass, not that these substances do not contain electricity, because it has been shown that it may be excited on them. On the other hand, if a metal be rubbed and applied to the sensitive electroscope it will be found to have no effect on the gold-leaf, because, though current is generated, it is conducted away. A comparative list of substances which are good, poor, and non-conductors of electricity can be readily compiled. Metals and carbon come under the head of good conductors; silver, copper, platinum, iron, zinc, and mercury are the best. Poor conductors include water, saline solutions, acid solutions, the body, etc. Non-conductors include glass, vulcanite, paraffin, sealing-wax, dry skin, dry air, etc. Every conceivable thing might be included under one of these heads, those mentioned come most frequently under our notice. There is a certain amount of resistance offered to the passing of electricity even by the very best conductors, the comparison of the conductors depends entirely on this property of resistance, but even those substances known as insulators convey a certain amount of current. (The amount they allow to pass in some instances becomes dependent on the electrical force which repels the current.)

During conduction of electricity, heat is always generated. This property depends on the amount of current which is passing and the resistance which is present.

From the foregoing it may be concluded that there is no demarcation between conductors and insulators. All substances may be accounted conductors, but some conduct so badly that they are termed non-conductors. Even these are at times affected by their physical state. The skin, for example, when perfectly dry is a very poor conductor, but when moistened is a fairly good conductor. Inversely, good conductors are similarly affected by their

physical state. Metals when heated become poorer conductors, whereas heat increases the conductivity of carbon. Pure water does not conduct, but acidulated water, or water to which is added a small quantity of salt becomes a good conductor. The reason for these effects of the physical state on the conductivity of current will be referred to later. The conduction of electricity through gases should not be lost sight of, for it has a bearing on the action of the current in passing through certain vacuum tubes like the x-ray tube.

Induction.—It has been stated that all bodies more or less contain electricity, which if it is not manifest, one reason is that it is evenly distributed, and that it may be excited and made manifest in different ways. The glass rod, for example, contains electricity, which can be excited by rubbing with silk. If the electrified glass rod is brought near to a suspended insulated pith ball it will attract it. The explanation of this is that the positively electrified body brought in proximity of the body which contains a certain amount of electricity evenly distributed over its surface, causes an alteration in the distribution of electricity by *inducing* negative electricity to the surface nearest to the charged rod, and as unlike attracts, the light body is drawn toward the electrified rod. Induction takes place whenever an electrified body is brought near another body. If an insulated substance is touched by the electrified body it will become charged with electricity of the like sign, but if the electrified body be removed without touching, the distribution of electricity in the other becomes once more evenly dispersed over its surface. If the insulated body instead of being round be pointed at each end, and another insulated positively electrified body be brought near one end, it will induce current of a negative sign to the point, where the density will become so great, that if they are brought close enough a discharge across the intervening space in a spark will take place, neutralizing the electrified body and leaving itself charged with electricity of the opposite sign.

Static Machines. — The current produced by frictional machines is the most ancient form of procuring a continuous current of electricity for therapeutic purposes. One older type of machine was constructed on the principle of generating a current by friction of a revolving glass cylinder with an amalgamated leather rubber. The negative electricity generated on the rubber is conducted to earth with the aid of the amalgam, and the positive electricity on the glass attracts a negative charge from a stationary metallic prime conductor placed in close proximity. A negative charge from the prime conductor neutralizes the positive charged glass cylinder, and retains a charge of positive electricity, which can be conducted from the prime conductor. This form of machine has been superseded by improved induction or influence machines. One type, long known and used, is the Holtz machine, which, with the many modern improvements, is still very popular. In this country the *Wimshurst machine* seems to be preferred. It has the advantages of being self-exciting, and does not reverse the current generated under climatic influences while in action. "It consists of two circular glass disks (or any even number), mounted in pairs upon a fixed horizontal spindle in such a way that they rotate in opposite directions at a distance apart of not more than a fraction of an inch. Each disk is attached to the end of a hollow boss of wood, or of metal, upon which is turned a small pulley. The pulleys are driven by a cord or belt from larger pulleys attached to a spindle below the machine, and rotated by a winch handle or by a motor, the differences in the direction of rotation of the disks being obtained by crossing the alternating belts. Both disks are well varnished, and attached to the outer surface of each of these are radial sector-shaped plates of tin-foil or thin brass disposed around the disks at equal *angles*. These sectors are not essential to the action of the machine but they make it more easily self-exciting.

"Twice in each revolution the two sectors situated on the same diameter of each disk are momentarily placed in metallic connection with one another by a pair of fixed

wire brushes attached to the ends of a curved rod, called the neutralizing rod, supported at the middle of its length by one of the projecting ends of the fixed spindle upon which the disks rotate, the sector-shaped plates just grazing the tips of the brushes as they pass them.

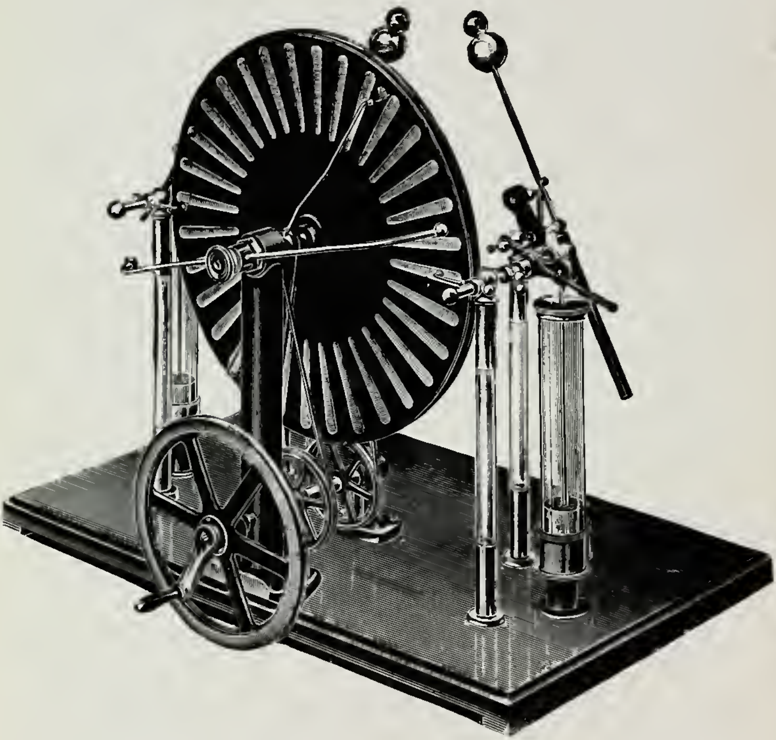


Fig. 3.—Wimshurst machine.

"The position of the two pairs of brushes with respect to the fixed collecting combs and to one another is variable, as each pair is capable of being rotated on the spindle through a certain angle, and there is one position of maximum efficiency. This position in the machine appears to

be when the brushes touch the disks on diameters situated about 75° from the collecting combs, and 30° from one another.

"The fixed conductors consist of two forks furnished with collecting combs directed toward one another, and toward the two disks which rotate between them, the position of the two forks, which are supported on ebonite pillars, being along the horizontal diameter of the disks. To these fixed conductors are attached the terminal electrodes, whose distance apart can be varied. Leyden jars are usually fitted to the machine by the makers, but these must admit of their outer coating being disconnected, if the machine is to be used for treating patients."[1] There are many modifications of the Wimshurst machine, some having ebonite plates, others mica disks. These substances permit of driving the machine at a high speed without fear of breaking the plates. All, however, are made on the principle of the above description of a frictional machine here quoted.

[1] Lewis Jones: Medical electricity.

CHAPTER II.

GALVANIC ELECTRICITY

Volta's Contact Law—Electrolyte—Voltaic Cells—Electro-motive Force —Practical Electrical Units—Resistance—Heat Effect of the Current —Polarization — Poles — Testing the Poles — Electrolysis — Ions — Electro-positive and Electro-negative.

Galvanic electricity is generated by galvanic or voltaic cells and by dynamos. It is the form of current which is most used in electro-therapeutics. Its force and current-strength can be graduated and controlled at will. This form of current is universally in use in the world's commerce, for which purpose it is generated by dynamos. Thus it is often termed Dynamic Electricity.

Discovered by Galvani in 1780 and improved in method of production by Volta in 1800, it often bears the names of these eminent students.

Galvanic electricity is produced when two dissimilar conductors are immersed in a liquid medium, called an electrolyte, which has the power of acting chemically on one of them more than the other—the metals being joined outside the liquid; that is, a circuit is formed, and the current will flow between the two metals within the fluid and be conducted along the plates and connecting wire.

It is necessary to dwell upon and study the foregoing statement that two *dissimilar* substances are required to form a current-producing cell.

If the metals or plates of a cell are exactly alike or even very similar and are immersed into a fluid electrolyte, which is capable of acting chemically upon them, no electric current will be produced; for example, if two zinc plates or two copper plates are placed in a solution of weak sulphuric

acid and the plates connected without by wires, on testing the wires connecting these similar plates no current will be found to pass, but if a zinc plate and a copper plate are immersed in a similar acid solution and connected by copper wire a strong electric current will immediately flow from the zinc to the copper within the solution and then along the copper plate and copper wire connection without in a continuous circuit.

Electrolytic conduction only occurs by chemical action, as will subsequently be explained, and it is necessary that the metals or conductors employed must have different affinities for oxygen. This law is observed in the construction of all galvanic cells.

The potential or electro-motive force depends on the amount of chemical action of the electrolyte on the substances employed, and this potential difference is governed by the dissimilarity in the chemical affinities of the plates employed. If, for instance, platinum and copper be brought together in a cell, the copper would become positively electrified and the platinum negatively, and the current produced by such a cell would be feeble compared to one composed of zinc and copper, both of which are oxidizable, the zinc in this case being more highly so becomes positively electrified and the copper negatively; the potential of the current from this cell is much greater than the other.

Zinc is one of the most oxidizable metals and most easily acted upon by electrolytes. It is therefore much used in the formation of voltaic cells. Copper, carbon, and silver are very dissimilar to zinc and are often used as negative elements in the construction of cells where zinc is the positive element.

Volta's Contact Law.—To Volta is due the discovery of the manifestation of difference in potential by contact of dissimilar metals in air, and also, as is known in the construction of cells, that the size or form of the metals does not affect the potential, but only their dissimilarity and the nature of the metals employed. The electro-motive force which can be obtained by bringing together two metals in

an electrolyte varies as the degree to which one becomes electro-positive and the other electro-negative when in contact.

Lists have been arranged according to Volta's contact list, in which each substance or metal in the list will be positively electrified when in contact with any metal succeeding it, and *vice versa*, negatively electrified in contact with any metal preceding it on the list. In the list the farther removed from one another in the series the greater will be the electro-faction of the metals if brought together in contact; thus zinc and carbon will have a potential difference far greater than zinc and iron.

Such a contact series is as follows:

Sodium.	Copper.
Zinc.	Silver.
Iron.	Gold.
Lead.	Platinum.
Tin.	Carbon.

According to Volta's contact law, "The difference of potential between any two metals is equal to the sum of the difference of the potential between the intervening metals in the contact series."

In the construction of galvanic or voltaic cells the metal plates are usually chosen with due respect to their difference of potential, but other properties have also to be taken into account, *e. g.*, sodium is never used, although between it and carbon there is one of the highest potential differences, because it would not be manageable for a battery.

The Electrolyte.—The electrolyte of a cell is the excitant and conductor of current. It acts chemically on the two elements and conveys electrically charged atoms from one to the other when the circuit is closed.

Among the commoner fluids used as electrolytes in galvanic cells are dilute sulphuric acid, ammonium chloride, persulphate of mercury, etc.

Voltaic Cells.—To construct a voltaic or galvanic cell, select any two of the dissimilar metals from the foregoing

contact series, the one farthest removed from one another will be the most highly electrified when placed in an electrolyte, which has a greater chemical action on one than the other. Take zinc and copper for the elements, and sulphuric acid; immerse the two metals in the acid, connect the ends outside the vessel with wires (see Fig. 4). As soon as the contact is made a continuous current will flow from the zinc through the liquid to the copper; this is the stronger current set up by establishing a potential difference between the two elements—that is, electrifying one element positively and the other negatively. The positive (+) electricity on reaching the opposite element is conducted by it to the wire connection without the cell, and conveyed back to the zinc again through the electrolyte, making a complete circuit, which will go on until the electrolytic strain on the higher potential is reduced to equilibrium by the ceasing of chemical action of the electrolyte on the elements, either by their destruction or by the conversion of the oxidizable surface through the deposit of some chemical product of a less electrostatic nature.

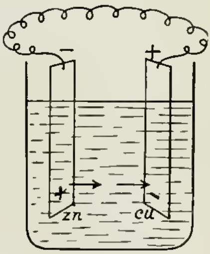


Fig. 4.—Voltaic cell.

The actual passing of current through the conducting fluid is effected by the splitting of the H_2O molecules, by the electrolytic effect of the current into hydrogen and oxygen atoms—ions, *i. e.*, atoms carrying electrical charges. The hydrogen ions are charged with positive electricity, and move toward the copper, where they give up their charge of positive electricity to the metal and hydrogen is liberated. At the same time the oxygen ions move toward the zinc where they give up their charge of negative electricity, and oxygen is liberated or unites chemically with the metal.

Electro-motive Force (E. M. F.).—When electricity is excited by the proximity of two dissimilar metals in an electrolyte, or by dynamos or by whatever means produced, that force which sets the current in motion, that which

separates the positive from the negative current is called electro-motive force (E. M. F.).

It is that pressure or potential of the current between the positive and negative poles, which always flows from the positive to the negative pole and will continue in that direction until equilibrium of pressure or potential is established. "It is that which produces, or tends to produce, movement of electricity."[1]

The analogy of the flow of electric current to that of the flow of water is often made in text-books, the difference in the level of the water being used in the stead of the difference in the potential of electricity, the point being there must always be a difference of pressure or potential in order to have a flow, and the greater the pressure the greater is the flow. In thinking of this analogy of pressure resembling the flow of water from a higher to a lower level, the thought of the lesser current must not be eliminated, for one kind of current cannot flow continuously without the other.

E. M. F. when applied to a conductor like metal propels continuously irrespective of altitudes or position, from the greater to the lesser potential; when applied to an electrolyte, it is also continuous from the positive to the negative.

The earth is always electrically charged, but there is a balance of potential between the positive and the negative electricity. The earth's potential is less than any current in motion, and consequently electricity in motion is always directed toward it. If we touch an electric motor lathe or the terminals of a switchboard, which are electrically connected with current from the main, and at the same time make contact with a gas or water pipe, which is in good contact with earth, the current from the high potential electrical source will be conducted through the body to earth, producing a disagreeable shock.

In the construction of voltaic cells the electro-motive force varies, and depends not on the size of the cell, but on the dissimilarity of the metals or "plates" which enter into

[1] Ashford: Electricity and Magnetism.

their formation. The degree to which one metal becomes more highly electrified than the other, and that tendency of the current produced between the metals in a conducting fluid to move from the higher to the lower potential establishes the electro-motive force of the cell.

The electro-motive force can be measured according to Ohm's law, by ascertaining the resistance and the current strength and multiplying them together.

$$E = CR$$

where E is the electro-motive force
C is the current strength
and R is the resistance

If we know any two of these factors we can calculate the third thus:

If the resistance of a cell and the resistance of the external circuit are together 1000 ohms and the current strength is 0.001 ampère (1 milliampère),

$$1000 \text{ ohms} \times 0.001 \text{ ampère} = 1 \text{ volt E. M. F.}$$

in this way we ascertain that the E. M. F. of the cell is 1 volt.

The current, the E. M. F., and the resistance can be measured by suitable instruments, which will be described in another chapter.

It has been stated that the E. M. F. of a cell depends on the plates which enter into its formation, and reference has been made to the "volt," but it has not been pointed out what the volt is. Different cells, according to the foregoing, vary in the E. M. F., and we require some standard with which to compare the E. M. F. of cells.[1] "The most natural thing to do is to take some cell, which can easily be set up, as having unit E. M. F. But there is a certain E. M. F. which depends on the fundamental units, the centimeter, the gramme, and the second, together with the magnetic action of a current of electricity, and it is most

[1] This is quoted from Ashford's Electricity and Magnetism.

convenient to take this, or some simple multiple of it, as the unit of E. M. F. The name given to the practical unit of E. M. F. is the volt, in honor of Volta.

"Unfortunately, no cell has exactly this theoretical E. M. F., but by careful experiments it has been found that a certain cell, called Latimer Clark's Standard, if made up accurately to a certain specification and measured at a temperature of 15° C. has an E. M. F. equal to 1.434 of these theoretical volts.

"This cell, then, can be used as a standard, just as conveniently as if it had an E. M. F. of 1 volt; other cells can be compared with it, and their E. M. F. calculated."

Practical Electrical Units.—The system of measurements of electrical units is based on the scientific calculation which is known as the absolute system. This starts by taking the unit of length, the *meter*, as a definite fraction of the earth's circumference. The unit of surface is obtained from this. For the unit of weight a smaller quantity is wanted, and the unit employed is the weight of a cubic centimeter (1 cubic meter = 1,000,000 cubic centimeters) of pure water at 4° C (the temperature at which it possesses its greatest density as it expands again between 4° and 0° C. For the unit of mass the *gramme*, and for the unit of time the *second* or the centimeter-gramme-second (C. G. S.) system.

The units with which we are most concerned are the Ohm, Volt, Ampère, Coulomb, Farad, and Watt, and these are all based on the C. G. S. system.

The Ohm is the unit of resistance (R). It represents the measurement of whatever opposes the passing of current in any circuit. In calculating resistance to current produced by a voltaic cell the resistance opposed in circuit outside the cell (whether it is only the wires connecting the elements or whether it is a body in circuit) is estimated as external resistance (R) and is added to the resistance which is offered to passing of current from one element to the other through the electrolyte within the cell and through the element itself and termed internal resistance (r).

The ohm is the resistance offered by a column of pure

mercury 106 cm. high and 1 sq. mm. cross-section at a temperature of 0° C.

Resistance varies in different conductors; iron wire, for example, has about six times the resistance of copper wire.

The Volt (V) is the practical unit for electro-motive force. It is the pressure that will cause the current flowing through 1 ohm of resistance to be 1 ampère.

The electro-motive force of the *Daniell* cell is sometimes used as the standard unit. It is about 1.079 volts, but varies with variations in concentration of the solutions used, and is consequently not as good a standard to go by as the Latimer Clark's cell (see p. 34), but the *Daniell* cell is one of the best-known two-fluid cells and is often referred to as the standard unit cell producing about 1 volt electro-motive force.

The Ampère is the unit of current strength (C). It represents the current which is furnished by an electro-motive force of 1 volt passing through a resistance of 1 ohm. This amount or quantity of current strength is far in excess of what is required in electro-therapeutics. It is therefore further divided into one thousandth of an ampère and termed the milliampère (0.001 ampère).

The Coulomb is the unit of quantity. One coulomb is the quantity of current which flows past any point in a circuit of one ampère current strength for one second.

In calculating the quantity of current which discharges from accumulators the term ampère-hour is used, which indicates the quantity of current which will be carried by one ampère in one hour.

"The standard value of the coulomb is equivalent to the quantity of electricity that will flow through or into a body when a current-strength of 1 ampère is maintained for one second,"[1] *i. e.*, if we are passing a current of 5 milliampères through a patient for 20 minutes the number of coulombs that have been applied is

$$0.005 \times 20 \times 60 = 6.$$

[1] Dawson Turner: Practical Medical Electricity.

The Farad is the unit of capacity. It is that capacity which would require 1 coulomb to charge it to 1 volt. A condenser which is of a given capacity must contain a given area of metallic conductor lining to charge it to the potential of 1 volt.

The Watt is the unit of electric power. It is the volt-ampère. A current of 1 ampère with a potential of 1 volt has a power of 1 watt, or a proportionately smaller current strength and greater electro-motive force will produce the same power; for example, $\frac{1}{10}$ ampère and 10 volts will produce one watt. The number of watts is determined by multiplying the number of ampères by the volts. 736 watts are equal to one horse-power.

Resistance.—It has been stated that conductivity of electricity by solids varies greatly with the nature of the material. Resistance may be said to be the inverse to conduction. Metals are accounted the best conductors, but however good the conductors an amount of resistance is encountered on the passing of electric current. The amount of resistance varies according to the kind of conductor, the nature of the material has an influence on the resistance; certain pure metals, which offer least resistance to current are changed by being alloyed. Copper, for instance, offers little resistance to current, but when alloyed to form German silver (copper 60 parts, zinc 26, nickel 14) has a high resistance.

The resistance varies directly as the length and inversely as the *square* of the diameter.

A metal wire of a given length has twice the resistance of a similar wire of half that length; so, too, if the diameter of a given length of a conductor be increased by twice, the resistance will be reduced to one-quarter the other.

The resistance of metal conductors is therefore dependent in individual cases on the nature of the material, the length, and diameter.

With the exception of a few alloys, raising the temperature increases the resistance of metals; the resistance of carbon is decreased with raising the temperature.

A table of resistance of metals in comparison of a similar length and thickness would work out as follows:

Silver	1.00
Copper	1.06
Gold	1.38
Aluminium	1.94
Platinum	6.08
Iron	6.80
Lead	13.60
Mercury	62.50

If the resistance of a given length of silver wire of a given thickness be ascertained, the resistance of any of the others may be calculated from this table.

The conduction of liquids excepting mercury is, as has been explained, of quite a different nature; some are almost non-conductors of current, as oils for instance.

In passing a current through a liquid resistance, as in the electrolyte of a cell, decomposition takes place. The body comes under the heading of liquid conductors, and various tissues and liquids in its composition have a greatly varying resistance.

To calculate the resistance the current meets in an electric circuit derived from a cell, the *internal* resistance, that is, resistance met chiefly in the electrolyte within the cell between the exciting plates, must be taken into account and added to the *external* resistance, which is the resistance met in the metallic conducting wires, and whatever body is interposed between the two terminals or poles.

To calculate *resistance, current strength* and *electro-motive force* it is necessary to have a clear conception of the law laid down by Ohm, which deals with the relation of force or potential to current strength and resistance.

Ohm's Law.—"The strength of the current in any circuit or part of a circuit varies directly as the electro-motive force in that circuit, and inversely as the resistance of the circuit."

To clearly understand this law examples of its equations explain it more fully.

Let E stand for electro-motive force in volts, C for current strength in ampères, and R for resistance in ohms.

$$\text{Current strength} = \frac{E}{R}$$
$$\text{Electro-motive force} = CR$$
$$\text{Resistance} = \frac{E}{C}$$

From these equations it is easy to calculate C, E, or R by a simple algebraic sum. To find the current strength (C) when E. M. F. is known to be 18 volts and R 1500 ohms:

$$C = \frac{18}{1500} = 0.012 \text{ (ampère)} = 12 \text{ milliampères.}$$

To find electro-motive force when R is 2000 ohms and C is 0.008 ampère:

$$E = 0.008 \times 2000 = 16 \text{ volts.}$$

To find resistance when E is 18 volts and C is 0.006 ampère:

$$R = \frac{18}{0.006} = 3000 \text{ ohms.}$$

The practical application of Ohm's law contributes to our proper understanding of much we have to study in electro-physics. In practice much interest is added to our electro-therapeutics by calculating the resistance of different patients, and it will be found, if this is done, that resistance of the body varies in a remarkable manner in different patients.

Heat Effect of the Current.—One of the effects by which the presence of current can be ascertained in passing through a conductor is the heat produced. The amount of heat produced may not be sufficient appreciably to raise the temperature, but if the current is sufficiently large and resistance high enough, in time the temperature of the con-

ductor will be raised to appreciable heat or even red or white heat. The quantity of heat produced by the passing of a definite current through a definite resistance in a given time has been calculated by Joub, who formulated a law which says that "the number of units of heat generated by a current in a conductor is proportional (1) to its resistance, (2) to the square of the strength of the current, (3) to the time during which it flows." From this law can be calculated the quantity of heat produced when a given current flows through a circuit with a given resistance in a given time. The energy absorbed by the resistance of the circuit is dissipated in the form of heat. The energy utilized in the production of heat is dependent on the resistance of the conductor. Thus when we want to produce great heat, as in a cautery, a strong current strength is passed through a small area and length of platinum wire which affords a great deal of resistance. If a good conducting wire like silver is used, the resistance of which is one-sixth that of platinum, a much greater current strength will be required to heat the wire to redness. The part resistance plays in respect to energy in the production of heat when a current is passed through different conductors may be amplified by the experiment of passing a current through a small chain consisting of alternate links of platinum and silver; when the current is sufficient to produce red heat in the platinum links the silver links will remain unheated perceptibly.

The resistance of the filament of an incandescent lamp has to be great, and the production of light is in consequence of the raising of the temperature to white heat in a vacuum, the resistance required and the current employed being dependent on the E. M. F. and the candle power of the lamp.

The heating properties of the current passing through a wire of small dimensions and known resistance has been utilized in construction of hot-wire instruments for the measurement of alternating and high-frequency currents, where magnetic instruments would be useless. Milliampère meters

are constructed for this purpose on the principle of heating; by the passage of the current a fine platinum wire is heated and by expansion caused a pointer attached is rotated over a scale which indicates the current.

In the practical use of the current the heating effect can be noticed when the author's method of bleaching dead teeth is carried out. If two fine platinum wires are inserted at two points in the dentine and the bleaching agent interposed as the conductor and completer of the circuit, when current strength of over 10 milliampères is passing, the whole structure of the crown of the tooth becomes perceptibly heated, and if the current strength is raised for a minute or two to 15 milliampères the heat becomes intolerable to the patient.

One of the effects of general electrization by high-frequency currents is the production of heat, an increase of the surface temperature of the body frequently takes place and the patient feels warm.

D'Arsonval has shown that under the influence of auto-conduction the heat given off from the body is greatly increased.

Polarization.—This term is applied to an obstructing of the current in chemically formed cells and has to be reckoned with in considering the resistance to current within the cell. It is brought about by an alteration of the surface of the plates of the cell during the chemical action which excites the flow of current, usually by the accumulation of hydrogen gas on the negative plate. Take, for example, a simple galvanic cell composed of zinc and silver with an electrolyte of ammonium chloride; on closing the circuit electricity flows within the cell from the zinc to the silver and electrolysis takes place, the hydrogen ions pass to the silver plate, discharge their current to the conducting metal, and hydrogen gas accumulates on the surface of the plate which it coats with bubbles. These bubbles act as a buffer or resistance to further electrolytic action. At the same time oxygen ions migrate to the zinc plate, discharge their electric charge, and act chemically on the zinc to form

oxide of zinc. The polarization of the silver plate by the coating of hydrogen bubbles on its surface changes that element from one of dissimilarity to the zinc to practically one of great similarity; the relative potential is altered. This is opposed to Volta's contact law, which says that in order to produce flow of current it is necessary to connect two dissimilar elements in an electrolyte.

To overcome polarization in cells, makers devise different methods to eliminate the gases or neutralize the chemical product which accumulates on the plates during the working of the cells. This is called depolarization. It may be accomplished to a certain extent by mechanical means, but the method most commonly used is the introduction of some chemical which by its affinity for the polarizing product unites with it to form some other product which does not affect the action of the cell, and rids the plates of the polarizing effect. The depolarizer lessens the internal resistance of the cell, which would increase as the current continued to flow and the E. M. F. would gradually fall. Hydrogen gas on the negative element is the most frequent polarizing product of a cell and the method of depolarizing is generally a chemical one, by the presence of some oxidizing agent which unites with the hydrogen as fast as it appears on the surface of the plates. In the Leclanché cell, manganese peroxide is the depolarizer; in bichromate of potash cell, chromic acid; in the persulphate of mercury, persulphate of mercury.

Poles.—In all chemical cells the flow of current is from the positive (+) element to the negative (−) *within* the cell; that is, from the greater potential to the lesser, but it must not be forgotten that there is also a weaker current which flows in the opposite direction from (−) to (+). When the current of higher potential (+) passing through the electrolyte reaches the negative (−) element it is conducted by it outside the cell to the end which is called the *terminal;* therefore the negative element without the cell becomes the *positive pole,* because it conveys the current of higher potential, and the positive element becomes the

negative pole. A study of the accompanying illustration will serve to explain how the current flowing in a closed circuit from a cell has the + pole at the terminal of the negative element.

TESTING THE POLES.—The chemical action at the + pole in a circuit is acid and at the – pole alkaline; that is, when current flows through a liquid separating the terminal in the circuit. Many simple tests which are useful in determining the poles are based on the acidity and alkalinity of the respective poles.

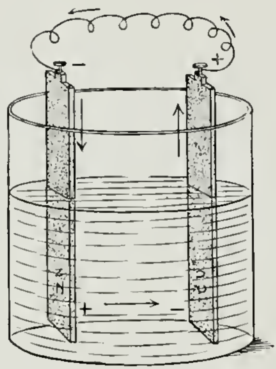


FIG. 5.—Direction of current inside and outside cell.

To find the poles: 1. Moisten a slip of blue litmus and place it on a glass slab, apply the electrodes conveying current from two poles of a battery or whatever source of electricity, about 3 cm. apart, the paper will turn red at the + pole.

2. A few drops of phenolphthalein (a clear, colorless liquid) in a glass of water and two metal electrodes placed 3 or 4 cm. apart in the water, with a current in circuit, will give a bright purple coloring to the water about the – electrode. The commonly employed testing paper is paper impregnated with this solution.

3. A simple and convenient method is to immerse the wires from the terminals of the cell in water containing a

little salt or acid; a few small bubbles collect on the positive pole and tend to stick to it and grow larger, while a number of minute bubbles collect on the negative pole and tend to leave it rapidly and rise to the surface of the liquid.

One of these tests is often a handy means of determining the poles when dealing with current from the main, in using a switchboard, even though the poles are marked; the plug connecting the board may become reversed and the identity of the poles lost. A milliampère meter attached to a switchboard is always an indicator of the constancy of the poles; if the plug is reversed the current in passing through the instrument will deflect the needle in the opposite direction to that marked on the terminal on the board, indicating the change in direction of the flow of current.

Electrolysis.—It has been pointed out that when two dissimilar elements are connected in an electrolyte or exciting fluid, a current flows from the positive to the negative element within the cell and that a chemical action takes place within the cell.

A similar chemical action takes place when current collected from a cell or other source of electricity is passed through a liquid or compound or tissue outside a cell or other electrical source of current supply between the two terminals.

If we place two platinum electrodes in a vessel containing water and pass a current through the water, bubbles of gas will rise from each electrode which will be found to be oxygen at the positive and hydrogen at the negative electrode, the formation of these gases would take place exceedingly slowly, hardly at all, because *pure water is almost a non-conductor* of current, and is only mentioned here as an example of the splitting of a liquid by the action of the current.

Electrolysis may be defined as "the process of splitting up a liquid chemically by passing an electric current through it." The liquid is the *electrolyte*, the positive electrode is called the *anode* and the negative electrode the *kathode*.

Now if the water in the foregoing experiment contains

a salt in solution it becomes a good conductor of electricity and the electrolytic action is greatly increased. The action of the current on a large class of compounds dissolved in water or other solvent may be explained by taking one of the simplest salts, sodium chloride (NaCl) for example, which in the solid state consists of molecules composed of one atom of sodium and one of chloride, when dissolved in water a certain number of the molecules dissociate into atoms of sodium and chlorine, *these atoms* move about in the solution in no regular formation and with no particular destiny, and are the *ions* when electricity is passed through the solution.

The effect of the current on such a solution is to cause decomposition of the solution (or electrolyte), the molecule NaCl is split or dissociated into the ion Na, which becomes positively charged and the ion Cl which becomes negatively charged. The charge of current is equal in each case. The positively charged ion moves toward the negative electrode and the negatively charged ion toward the positive electrode. In this manner electric current passes through the electrolyte, the ions conveying definite charges of electricity, and oxygen is liberated at the anode and hydrogen at the kathode.

But in the case of an electrolyte containing a salt and an alkali metal, the action is often far more complicated; it may be found that when the molecule is split one of the electrically charged atoms is composed of a chemical compound of an unknown composition, in which case the atom may combine with one of the atoms of water to form a new chemical compound.

Take, for example, copper sulphate, $CuSO_4$, if this is electrolyzed between *platinum* electrodes, the Cu ion moves to the kathode and copper is deposited on the platinum and hydrogen is liberated, the SO_4 ion (which is called *sulphion*, but is not a chemical compound) moves to the anode, where it unites with some of the water (H_2O) to form sulphuric acid (H_2SO_4) and oxygen is liberated.

If the same salt is electrolyzed between copper electrodes

there is a further effect produced, another reaction takes place, the sulphion (SO_4) instead of uniting with the H_2 atom of water, attacks the copper anode and forms copper sulphate ($CuSO_4$) after giving up its charge of electricity to the electrode, and the metal is in the course of time reduced in weight by the loss of copper ions which go into the electrolyte and replenishes it. At the same time the copper ion (Cu) is deposited on the cathode after giving up its charge of electricity, and this electrode is increased in weight at the expense of the other.

If sodium sulphate ($NaSO_4$) is electrolyzed between platinum electrodes a still further effect will be produced. There will be a secondary action at *both* electrodes. The following action takes place, the sodium sulphate is split into sodium and sulphion, the *sodium* (Na) ions become positively charged and move toward the kathode, where the electric charge is given up and the sodium unites with hydrogen of the water, forming sodium hydrate and liberating hydrogen; the *sulphion* (SO_4) becomes negatively charged and moves toward the anode, where the electric charge is given up and sulphion (SO_4) unites with the water (H_2O) to form sulphuric acid (H_2SO_4) and oxygen (O) is liberated. If to this solution some neutral litmus is added before electrolyzing it a blue reaction will appear at the kathode and red at the anode, indicating alkalinity at the kathode and acidity at the anode.

The quantitative results of electrolysis were determined by Faraday, who by experiments discovered the relative quantities of substances liberated at the electrodes. He found that when the current is passed through a series of voltameters (or electrolytic cells) with the same electrolytes and the same electrodes that the weight of the product of electrolysis in each cell was the same, but when the electrolytes and the electrodes were different the product of electrolysis varied according to the chemical equivalent quantities; he therefore formulated the law: "*When a current passes through different electrolytes in series the ratio between the quantities of the substances appearing at the elec-*

trodes is the same as that of their chemical equivalents." A simple but clear explanation of this law is here quoted from Ashford as follows: "Suppose that a current passes through two cells in series containing respectively (A) acidulated water, (B) copper sulphate solution, both with platinum electrodes, and a third (C) containing copper sulphate solution with copper electrodes. Suppose that the current is allowed to flow until 1 gram of hydrogen has been liberated in A. To form the water in A, 8 grams of copper are combined with each gram of hydrogen, so that 8 grams of oxygen are liberated at the anode in A, and therefore also at the anode at B. Now 31.7 grams of copper are chemically equivalent to 8 grams of oxygen so that 31.7 grams of copper will be deposited on the cathode in B and therefore also in C Thus from Faraday's results we see that the following quantities are simultaneously liberated: Hydrogen 1, oxygen 8, copper 31.7. These numbers are the chemical equivalents of these elements."

Ions.—In the section on Electrolysis it was stated that the action of the current in an electrolyte is to split it up chemically into simpler materials which move to their respective electrodes. The term *ions* is given to these materials; that which travels to the anode is called the *anion,* that which goes to the kathode the *kation.* (The terms anion and kation although often used in reference to ionization are very misleading and difficult to construe and will be seldom used here, to avoid confusion.)

The ion is the conveyer of electricity. It is the product of a splitting up of the component parts of a compound and is associated with the idea of something which moves or is going in some direction.

Salts are formed by the chemical union of metals or metallic radicals with acid radicals; when a current is passed through an electrolyte containing a salt in solution, the *metals* or *metallic radicals* move *from* the *anode* to the kathode (hydrogen is included in these) and the acid radicals always move in the opposite direction, *i. e., from* the *kathode* to the anode. Those atoms which are split by the electrolytic

action of the current are the ions which carry definite charges of electricity and are set free at the respective electrodes to which they migrate. In the case of acids in the composition of an electrolyte they act like salts whose metal is hydrogen; thus in hydrochloric acid, hydrogen will appear at the kathode and chlorine at the anode.

Bases act like salts whose acid is hydroxyl (OH). Thus in potassium hydrate (KOH) the (K) potassium becomes positively charged and will appear at the kathode and the (OH) hydroxyl becomes negatively charged and will appear at the anode.

Leduc in explaining the migration of ions says: "The fragments resulting from the dissociation of molecules are the ions, and these ions are carriers of electric charges, to which the electrolytic conduction is due. The anions carry negative charges, and are consequently attracted by the positive electricity of the anode. The kations carry positive charges: they are repelled by the anode and attracted by the negative electricity in contact with the kathode. On coming in contact with the electrode, the ions are unloaded, neutralizing quantities of electricity equal to, and of opposite sign to themselves; and these quantities of electricity will be replaced by new charges coming from the generator, and it is thus that the electric current is produced and maintained.

"Plurovalent ions carry electric charges proportioned to their valency; or rather it is the electric charges which determine the valency."[1]

The rate of movement of ions in an electrolyte varies according to the electro-motive force and the direction of migration of the ions, those conveying positive charges moving faster than the negatively charged ions. "Hottorf has shown that the velocity of anions differs from that of kations. This may be proved by the following experiment: A solution of sulphate of copper is placed in an electrolyte cell with a porous partition, the solution being identical

[1] Leduc: Electric Ions and Their Use in Medicine.

on both sides of the partition. After passing a current for some time the solution is found to be more concentrated on one side of the partition. The anion SO_4 has travelled faster than the kation Cu, although the number of ions liberated at the electrodes is the same

$$\begin{array}{c|ccc|ccc|c} & SO_4 & SO_4 & SO_4 & SO_4 & SO_4 & SO_4 & \\ - & Cu & Cu & Cu & Cu & Cu & Cu & + \end{array}$$

Before the passage of current.

$$\begin{array}{c|cccc|ccccc|c} & & & & SO_4 & SO_4 & SO_4 & SO_4 & SO_4 & SO_4 & \\ - & Cu & Cu & Cu & Cu & Cu & Cu & & & & + \end{array}$$

After the passage of current.

"The ratio of the degree of concentration on either side of the porous diaphragm enables us to estimate the relative velocities of the anions and kations respectively."[1]

This experiment is also alluded to by Leduc, who points out that "Three ions are liberated at each electrode, but in consequence of the difference of the speed of the ions the negative half of the cell does not contain more than one molecule of sulphate of copper, having lost two-thirds of its concentration, while the positive half contains two parts, having lost only one-third of its concentration. It is easy to conclude from this that the ions move in opposite directions at different rates."

The rate of travel and the depth of penetration of ion when the electrolyte is a moistened tissue depends in a measure on the current strength and resistance offered in the particular tissue; that is, the molecular conductivity of the kind of electrolyte will influence the passing of ions, and this must be considered in their practical application; a liquid will convey ions at a rapid rate with little resistance, whereas gelatinous substances or a tissue will retard the rate of travel. The kind of tissue, whether a good electrolyte or an indifferent one, will influence the speed and penetration of ions. The penetration will also be considerably

[1] Guilleminot: Electricity in Medicine.

affected by the changes the ions undergo when they enter the tissue. Some are precipitated at once and only remain in the superficial layers, while others can be driven in to a great depth.

A simple ionic effect is furnished when the current is passed through an aqueous solution of zinc chloride, the zinc chloride molecules are dissociated by the effect on the solution, zinc ions charged with positive electricity migrate toward the negative electrode while the Cl ions become charged with negative electricity and migrate in the opposite directions.

A practical but more complicated illustration is found in gold plating, a process carried out in most dental laboratories. Here the electrolyte is cyanide of gold (8 KCN + 4 Au + O_2 + $2H_2O$), the positive electrode is a piece of pure gold (anode), the negative electrode is the piece to be plated (kathode), which may be gold, silver, copper, German silver, etc. By the electrolytic effect the solution is split into Au ions charged with positive electricity, which migrate toward the negative electrode to which they give up their charge of positive electricity and on which gold is deposited, at the same time the dissociated KCN ions migrate toward the positive electrode (gold) where they give up their charge of negative electricity, and here one of the complicated electrolytic effects takes place. The KCN atoms unite chemically with O_2 and the gold electrode to form gold cyanide which replenishes the solution with gold atoms. The atoms in the charged state are supposed to take on a regular formation and to migrate to their respective directions (Fig. 6). The velocity of migration of the gold ions varies with the drop in voltage and consequently with the current strength and also with the temperature of the electrolyte. If we desire to plate a piece with a thick coating of gold we use a strong current with a solution rich in gold ions and raise the temperature slightly.

The gas bubbles which collect at the electrodes are H_2 at the kathode and O at the anode, which are ions of the molecule H_2O charged, dissociated, and migrated in precisely

the same manner as the other ions of this compound solution.

Electro-positive and Electro-negative.—From the foregoing it has been pointed out that the action of the current on molecules of salts in solution is to split up the component parts into ions, which become positively and negatively charged and move in the direction of attraction of the particular ion, or, in another sense, to be repelled from one pole toward the other. The ions, which are positively charged, are repelled from the positive pole and carry a positive charge of current with them, these are termed

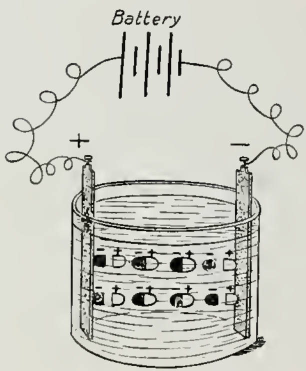


Fig. 6.—The supposed migration of ions.

electro-positive. Those which are negatively charged are repelled from the negative pole and are called *electro-negative.*

An example of electro-positive and electro-negative elements in an electrolyte-conducting current is often experienced in the mouths of patients whose approximating surface of teeth are filled with two dissimilar metals; take, for instance, two premolars, the posterior approximal surface of the first filled with amalgam and the anterior approximal surface of the second filled with gold, both fillings extending to the cervical margin, the secretions of the mouth provide an excellent electrolyte. In these cases if the metals

are slightly in contact at the articulating surfaces of the fillings a perfect cell is formed and current strength which is produced by such a cell is considerable—quite sufficient to cause considerable pain if the pulps are alive. It is likely that E. M. F. in such a cell is sufficient to produce a current strength of one or more milliampères. The author has tested fillings of this description and found that the discomfort complained of from the electric current produced by their proximity was greater than that produced by passing one milliampère of current through the fillings from a galvanic generator. According to Volta's Contact Law, amalgam in this tiny cell is positively charged and gold negatively, therefore the direction of flow of current when the circuit is closed is from the amalgam to the gold through the electrolyte, and ions conveying electric charges are electro-positive from the amalgam to the gold and electro-negative ions from the gold to the amalgam. These may eonsist of ions of any salt present. There are many medical solvents which are neither electro-positive nor electro-negative, that is, they do not permit of separation of ions, even when they contain those salts which in an electrolyte are readily dissociated.

Among these are alcohol, glycerine, vaseline, chloroform, ether, and oils. These are nearly all included in a list given by J. H. Morton,[1] of New York, of substances which are stated by him to be acted upon or conveyed by electric osmosis or cataphoresis.

There are many substances with which we frequently deal in electro-therapeutics that are formed by the union of metallic radicals with acid radicals; such compounds are sodium chloride, zinc chloride, copper sulphate, etc., which when acted upon by an electric current separate into electro-positive and electro-negative ions. The direction of migration of ions contained in a salt must be known in order to determine the proper poles to apply to medicate with the ions desired. For example, if zinc ions are required from zinc chloride and the negative electrode be applied

[1] Cataphoresis, p. 144.

to the site of medication, chlorine gas would be liberated without any migration of zinc ions.

All acid radicals are negatively charged and all basic radicals positively. The following are a few electro-chemical substances arranged under the headings of

Electro-positive.	*Electro-negative.*
Hydrogen.	Oxygen.
Mercury.	Nitrogen.
Copper.	Sulphur.
Iron.	Chlorine.
Zinc.	Bromine.
Sodium.	Iodine.
Potassium.	Arsenic.

By the foregoing it is clear that when a current is passed in a circuit through an electrolyte containing a salt in solution the dissociation of the component parts takes place, the ions formed convey the electrical charges positive or negative in opposite directions to the conducting electrodes, where they give up their charges. When they have lost their charges they reunite by the laws of chemistry with the elements in the electrolyte for which they have affinities. For instance, if sodium chloride is the salt and saliva the electrolyte in the cell referred to of amalgam and gold fillings between the teeth, when the Na ions conveying their charges of electricity reach the gold conductor they lose their charges and the Na unites chemically with OH ($Na + H_2O. = NaOH + H$) in the saliva to form NaOH. The Cl ions likewise lose their charges to the amalgam and the Cl unites chemically with the metal, tending to destroy it. These chemical changes take place at the electric elements of all batteries or cells, and it may reasonably be conjectured that this chemical change taking place in the instance of fillings of dissimilar metals between the teeth may be the cause of rapid disintegration of inorganic salts at the marginal edge of the fillings, when this product of electrolysis is an acid. Or, conversely, may be the means of preserving the marginal edges in the case of the product being an alkaline or antiseptic.

CHAPTER III.

CELLS.

Leclanché Wet and Dry Cells—Smee Cell—Bichromate of Potash Cell—Persulphate of Mercury Cell—Bunsen Cell—Grove Cell—Daniell Cell—Secondary Batteries or Accumulators—Edison Storage Battery—Arrangement of Cells—Cells in Series—Cells in Parallel—Cells in Multiple Arc—Density.

One of the important sources of supply of electric current for dental purposes is from cells. The principle of construction of a voltaic cell has been described on page 30. In the manufacture of cells, makers observe strictly the laws which govern the generation of galvanic currents, Volta's Contact Law, resistance, polarization, and depolarization. A constant and efficient supply of current from a cell depends on a combination of adaptability of the plates to these laws, the chemical action of the electrolyte employed, and the difficult question of polarization and depolarization.

Leclanché Wet Cell.—Of the many forms of primary cells the one which is most useful is the Leclanché cell. The *Leclanché cell* consists (1) of a glass jar in which is placed a porous pot containing in the centre a carbon rod surrounded by coarsely powdered carbon and peroxide of manganese, this forms the negative element; (2) a rod of amalgamated zinc, which forms the positive element; (3) the electrolyte consisting of a strong solution of ammonium chloride (sal ammoniac). These constitute the internal arrangements of the cell. The carbon is electro-negative and very dissimilar to zinc, which is electro-positive. The electrolyte ammonium chloride ($2NH_4Cl$) acts chemically on the zinc to form zinc chloride ($ZnCl_2$) ammonia ($2NH_3$) and hydrogen (H_2).

$$Zn + 2NH_4Cl = ZnCl_2 + 2NH_3 + H_2$$

By the action of the current generated when the circuit is closed, within the cell the ion NH_4 migrates to the negative element, and the ion Cl migrates to the positive element, conveying their respective charges of electricity which they unload to the conductor elements. The chlorine atom unites with the zinc to form zinc chloride; the ammonia is soluble in water and is dissolved in the electrolyte solution at the negative (carbon), the hydrogen collects on the negative element in the form of gas bubbles and causes polarization, but the carbon rod is surrounded with peroxide of manganese which is rich in oxygen, the hydrogen bubbles unite with the oxygen to form water, and by this means depolarization is effected. When the circuit is closed (that is, the elements connected outside the cell by a conducting wire) the cell gradually weakens, the polarization of the cell takes place faster than the depolarization, and the flow of current gets gradually less.

Fig. 7.—Wet Leclanché cell.

This kind of cell, however, has the property of recovering rapidly when the circuit is again broken, the manganese dioxide continues its action of depolarization until the cell is free from the collection of hydrogen gas on the negative element. The chemical action of this cell ceases when the circuit is broken, so that its elements are not continually acted upon and it is a most lasting and economical cell.

A collection of these cells makes a very useful battery for dental purposes, if kept in a cabinet and the water and ammonium chloride renewed when required, will remain active for a number of years, requiring very little attention. The zincs are destroyed in time by chemical action but they are readily replaced. When it is unnecessary to move the battery about, as is the case in a dental surgery, these cells are admirably adapted.

The electro-motive force (E) of the Leclanché cell is 1.47 volts; there is considerable internal resistance (r). The calculation of the current strength (c) can be readily carried out according to Ohm's law. It will be found that one cell is inadequate for dental purposes with the body in circuit.

Take, for example, the resistance of 1500 ohms for the body and roughly 0.25 ohm for internal resistance. The equation then is:

$$C = \frac{1.47\ V}{R1500 + 0.25r} = 0.001 \text{ ampère} = 1 \text{ milliampère}$$

It is therefore necessary to collect the current from a number of these cells by joining them in series in the form of a battery.

Leclanché Dry Cell.—This cell is made on the same principle as the wet cell described. Instead of the glass jar, the case of the cell is made of zinc which is used as the positive element; in the centre is the carbon negative element surrounded with a layer of manganese dioxide as the depolarizer. The electrolyte is a pasty substance composed of some preparation of ammonium chloride. The cell is sealed at the top and is of small size, the smallest measuring $1\frac{1}{2}$ x $1\frac{1}{2}$ x $3\frac{3}{4}$ inches. The current produced by one of these small cells is about equal to a wet cell of ordinary size and it will last a fairly long time. Internal resistance of the Leclanché cell is a factor in its construction, for which makers have devised several methods to overcome. Messrs. Schall & Son make one form which they supply in their batteries in which zinc is placed inside a cylinder of carbon, separated from it by the electrolyte.

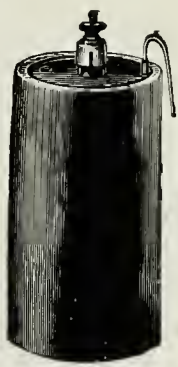


Fig. 8.—Leclanché dry cell.

The advantages of the Leclanché dry cell over the wet

are that they are encased in metal and are unbreakable; they contain no liquid which would be liable to spill, they are sealed, and there is no corroding of the terminals, the internal resistance is slightly less and E. M. F. slightly greater than the ordinary wet cell.

The principal disadvantage they possess is that they cannot be recharged, when used up they become worthless, but they last long enough to make this disadvantage hardly worthy of mention. Two years in constant use in a dental practice might well be the life of a dry cell.

The Smee Cell.—This is a simple cell made of plates of amalgamated zinc to form the positive element. These are placed parallel to each other and separated by a plate of silver coated with a thin layer of platinum to form the negative element. These two metals, zinc and platinum, are far apart in the contact series and the electro-motive force generated is greater than it would be if the negative plates were made of either silver or copper, platinum being more electro-negative to zinc than either silver or copper. The electrolyte consists of a weak solution of sulphuric acid. There is no chemical depolarizer in this cell, the depolarization is mechanical, that is, the gas bubbles are unable to cling to the surface of the platinum plate and the plate keeps comparatively clear of this polarizing agent, but it is an imperfect means of depolarizing.

The zinc of the cell must be withdrawn when the current is not being used, for the constant chemical action of the acid on the zinc destroys it.

The electro-motive force of the cell is about 2 volts and when in use it is rapidly reduced on account of the collection of hydrogen gas which collects on the negative plate. This type of cell has been much used in the past for electro-therapeutic purposes, but for dental work it has no advantage over the Leclanché cell.

Bichromate of Potash Cell.—This cell is constructed of a plate of zinc which forms the positive element, and two plates of carbon set one on either side of the zinc which form the negative element. The electrolyte is dilute sul-

phuric acid. A mixture of strong sulphuric acid, powdered bichromate of potash and water is the depolarizer. The electrolyte is sometimes varied by the use of chromic acid instead of potash, because its chemical action lessens the internal resistance. The chemical action of the cell is constant and the metal element is arranged so that it can be removed from the electrolyte when the cell is not in use. It is often made in the form of a bottle with a cork through which passes a rod attached to the zinc, which provides for the lifting of the zinc clear of the liquid when the cell is not being used.

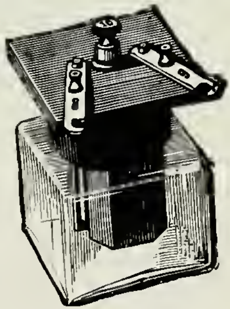


Fig. 9.—Bichromate of potash cell.

By the chemical action of the electrolyte on the plates when the circuit is closed, a strong electric current is excited, positively charged ions of hydrogen and metallic radicle pass from the zinc to the carbon element, at the same time negatively charged ions of oxygen and acid radicle pass from the carbon to the zinc.

The E. M. F. of the cell is about 2 volts. It is used when a strong current is required for cautery or small incandescent lamp or working an induction coil. With a few of these cells collected in parallel a very strong current is produced for a short time but polarization takes place rapidly within the cells and internal resistance causes a rapid fall in the current. It is a useful form of cell, being always ready for use and producing a strong current. Until recently small batteries made of this type of cell were much used for producing high current strength for cautery and it was probably the most important of the single fluid cells, but the advent of the accumulator and switchboard has detracted from this importance.

Persulphate of Mercury Cell.—This is another type of single fluid cell from which a high E. M. F. is obtained.

It is constructed of a zinc plate for the positive element,

carbon for the negative element, and persulphate of mercury in solution for the electrolyte—the depolarizer is persulphate of mercury. By chemical action, when the circuit is closed, hydrogen electro-positive ions appear at the carbon where they unload their electrical charges to that element and H unites with the persulphate of mercury in the electrolyte solution to form sulphuric acid and deposit metallic mercury.

The sulphuric acid thus formed acts on the zinc element. The chemical affinity of the hydrogen for the persulphate of mercury by which the gas bubbles are removed from the surface of the carbon constitutes the depolarizer.

The E. M. F. is 1.5 volts and the internal resistance is low. It is a much-used cell for medical purposes. Many improved forms have been invented in which the mercury in the electrolyte has been utilized to amalgamate the zinc and by improvements in the depolarization of the cell a constant and lasting cell has been made.

The cells described so far are all single fluid cells, there now remain to be described briefly one or two forms of double fluid cells; that is, cells in which each element is surrounded by a different fluid, one of which is the electrolyte and the other the depolarizer. Of these the Bunsen, the Grove, and the Daniell are the best known.

The Bunsen Cell.—This consists of a glass cell containing a zinc plate which forms the positive element, a porous pot containing a stick of carbon and a strong solution of nitric acid forms the negative element, the electrolyte is a dilute solution of sulphuric acid which is placed in the cell about the zinc and porous pot. The nitric acid is the depolarizer. By the chemical action of the cell zinc is acted upon by the sulphuric acid to form zinc sulphurite and liberate hydrogen ions which migrate to the negative element conveying positive charges of current, here the current is conducted away by the carbon, and hydrogen gas collects on the porous pot, the depolarizer (nitric acid) combines with the free hydrogen to form nitric-peroxide and water, and depolarizes the cell by dispersing the gas bubbles.

The current strength from this cell is greater than any of the single fluid cells, because of the small resistance within the cell by the perfect depolarization; the E. M. F. is about 2 volts, and internal resistance only a fraction of an ohm, and maximum current strength about 10 ampères.

The strong acid electrolyte of this cell soon destroys the zinc element, so that this cell is not a lasting one. The poisonous fumes of nitrogen peroxide, which are given off in the process of oxidization is a great objection to this form of cell; it should not be kept in a room with instruments.

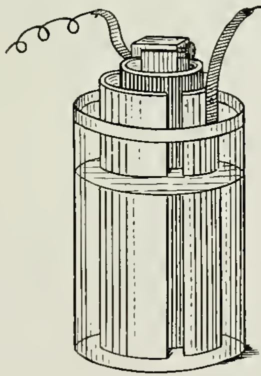


FIG. 10.—Bunsen cell.

It produces current for cautery loop or lamp and a battery of these cells can be used to charge accumulators where current from the main is not available.

The Grove Cell.—This cell has the same construction as the Bunsen which is a modification of it. The negative plate in the porous pot is platinum, but owing to the cost of this metal, carbon is substituted in the Bunsen cell, otherwise the fluids and their chemical action in the cell are precisely the same.

The Daniell Cell.—This cell is constructed with different variations of the following principle: The positive element

is a rod of zinc which is placed in the centre of a porous pot in the centre of the cell, the zinc is immersed in the electrolyte which is a dilute solution of sulphuric acid or zinc sulphate. The negative element is copper which forms the inner lining of the cell, the space between it and the porous pot contains a saturated solution of sulphate of copper, with usually some crystals of sulphate of copper to add to the supply of the salt in solution. The second fluid is the depolarizer of the cell.

By the chemical action of the H_2SO_4 on the zinc, zinc sulphate ($ZnSO_4$) and hydrogen (H_2) are formed; the hydrogen in passing from the porous pot combines with the copper sulphate ($CuSo_4$) to form sulphuric acid (H_2SO_4) and copper (Cu). The H_2SO_4 formed replenishes the supply of electrolyte. The copper ions unload their charge of current to the copper element and deposit copper on the lining of the cell. There is no polarization of the cell, as the hydrogen is used up in chemical combination with the copper sulphate and the copper deposited on the negative element merely thickens the copper lining of the cell.

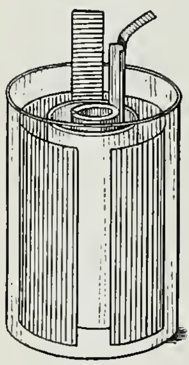


FIG. 11.—Daniell cell.

By the perpetual change of ions in this form of cell it remains active for a long time; the positive element (zinc) becomes destroyed in time but is readily replaced and the cell is then as good as new. The negative element (copper) will always remain active because it is being added to when the cell is working. The electrolyte is also replenished by the formation of H_2SO_4 at the porous pot.

The E. M. F. of the Daniell cell is a little over one volt and was originally taken as the standard unit of electromotive force, being sufficiently near the volt and being nearly constant.

The internal resistance is practically *nil*, but placed at

an estimate of 0.15 ohm the current strength from one of these cells would be:

$$C = \frac{1 \text{ volt}}{0.15 \text{ ohm}} = 6.6 \text{ ampères.}$$

Three of these cells connected in parallel will produce nearly 20 ampères current strength.

The disadvantage of all acid fluid cells is that the perishable element should be withdrawn from contact with the electrolyte when the current is not required; this leaves the cells open to evaporation of their fluid contents, and also the liquid is easily spilled. They are not as clean as the Leclanché cells and require replenishing frequently. The refilling, however, is not a difficult matter. In places where electrical supplies are not easily obtained the Daniell cell battery might be useful to those who have only occasional use for cautery and light, but their use has been almost completely superseded by the dynamos and secondary batteries (accumulators).

Secondary Batteries or Accumulators.—This type of battery is so constructed that when it runs down it can be again charged by passing a current through it. It is made, in one type, of thin plates of lead molded in the form of a grid, that is, holes punctured in the surface of the plates; these plates are placed close together but carefully separated by some insulator interposed at the top and bottom of the cell so that they are in no electrical contact except through the electrolyte, which consists of a solution of sulphuric acid (about 1 part to 5 of water). The plates which form the positive pole are pasted with red lead, that is, the holes of the grid are filled with the red lead; and the plates which form the negative pole are filled with sponge lead, all the plates of the positive sign are connected outside the cell by metal, bringing them to one terminal, and all the plates of negative sign are similarly connected, there being always one more negative than positive plate, and are alternately placed, a positive and a negative.

There are many variations in the method of construction of accumulators which it is unnecessary to enumerate or describe. This one gives the principle of the "storage battery" as it is sometimes called. The arrangement and number of plates is carried out with the intention of increasing the current with the least amount of potential, *i. e.*, it diminishes the internal resistance.

Four or six cells connected in series form a battery, each cell of which has a potential of 2 volts, making a total E. M. F. of 8 or 12 volts, according to the respective number of cells. The capacity of the cells varies according to the size of the plates, and the discharge of current is recorded in ampère-hours, *i. e.*, current can be maintained at a certain number of ampères for so many hours, *e. g.*, six cells with a capacity of say 24 ampères when charged may be discharged either at the rate of 1 ampère for 24 ampère-hours or 2 ampères for 12 ampère-hours or ½ ampère for 48 ampère-hours. When the accumulator is run down, which can be determined by an ampèremeter (usually called ammeter) in circuit, it can be recharged from the opposite direction to that in which it discharges. This is done by attaching the positive pole of the source of current for recharging to the positive pole of the battery and the negative to the negative of the battery. The recharging of an accumulator battery may be accomplished with current from a number of Daniell or Bunsen cells connected in series, having an E. M. F. of at least 10 per cent. higher than that of the battery to be charged, and the current must be allowed to pass for about 25 per cent. longer than the capacity of the cells, *i. e.*, a cell of 4 ampère-hours' capacity will discharge for 8 hours at ½ ampère, but must be charged for 10 hours at ½ ampère.

If continuous main current for lighting purposes is available it is far easier and cheaper to recharge accumulators from this source, provided the voltage of the main approximates to that of the accumulators or that suitable means be taken to reduce it.

In recharging accumulators the capacity of the cells should be taken into account and the charging current

measured with an ampèremeter and calculated in ampère-hours to correspond with the capacity of the cells; the rate of charging should not be too rapid; the most efficient rate being usually marked by the makers, and is usually about one-tenth the capacity. Those accustomed to the recharging of accumulators can determine when fully charged by the sound of effervescence of gases in the electrolyte of the cells, when they are only partly charged slight effervescence is audible, and when fully charged a distinct noise of active effervescence is heard within the cells.

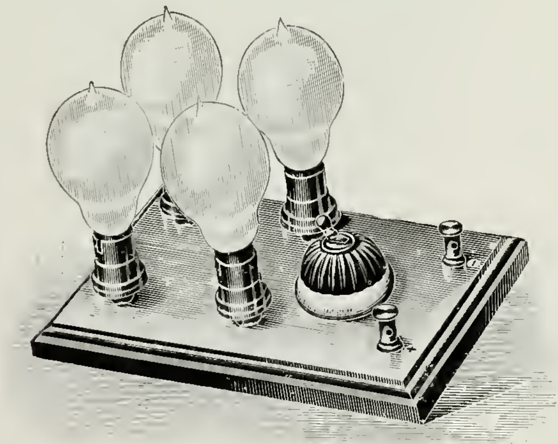


FIG. 12.—Resistance lamps.

In charging from the main, the correct poles of both source of current and battery must be determined, this can be carried out by methods already described (p. 42). The like poles of both are connected and a resistance, the amount of which is determined by the current required, is placed in circuit between the negative pole of the battery and negative of the current supply. The current is passed from the positive pole of the main to the positive terminal

of the accumulators, through the plates and electrolyte within the cells and out at the negative terminal, and through the resistance; carbon-filament lamps of different powers are often used as a cheap and convenient form of resistance, several usually being employed in parallel.

The accumulator is useful for heating a cautery loop and for lighting mouth lamps. It has a very useful place in the surgery, especially where the current is not available from a dynamo source. The battery is always ready for immediate use as long as it is charged: when run down it is easily recharged by sending it to the power house of a dynamo machine or to the makers, and it lasts for a number of years if properly cared for, the acid kept at the right strength, and if not allowed to run down completely before it is again charged or if not badly charged, that is, charged too quickly with too strong a current.

The modern form of switch-board which is made for use where dynamo current is available has quite superseded the secondary battery. It is certainly far more convenient for many purposes, which, until its introduction, the storage battery was the only available means of procuring current in that form—but the accumulator will always find a useful place in the surgery of dentists situated in places where the street current is not available or not installed, or where it is alternating and the current required is a continuous current, or where a portable battery is required.

The ordinary dental motor engine can be run by a collection of accumulator cells arranged in series, 6 cells will produce an E. M. F. of 12 volts, which is ample to run the dental engine indefinitely by keeping the cells charged.

The Edison Storage Battery.—This form of accumulator is one of the latest inventions of Mr. Thomas A. Edison, which bids fair to revolutionize the storing of electric current for many purposes, certainly for dental purposes there is no method more suitable. It does away with the lead and acid so objectionable in the lead plate form of storage cells, eliminates the element of care and knowledge necessary in the working of the lead cells, while the life of the cells is

increased many fold; reduced size and weight with the same storage capacity are improvements of great value. The cells are made in various sizes and numbered by the makers according to their capacity, the ampère-hour output depending on the number and size of the plates, but the voltage is the same, viz., 1.2 volts per cell. The voltage, it will be

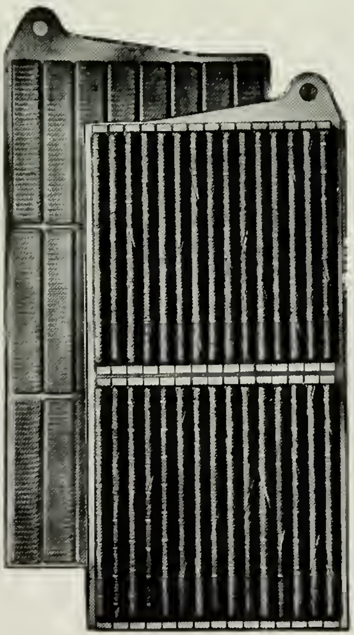


FIG. 13.—Positive and negative plates, A.4 type.

observed, is less than that of the lead cells. Each cell of A.4 type (which is the size which would make a useful battery for working a dental engine) contains four positive and five negative plates. "The negative plate is comprised of twenty-four rectangular pockets supported in three horizontal rows in a nickel-plated grid, each pocket being ½ inch wide and 3 inches long. The pockets are made of thin nickel-plated

steel, perforated with fine holes. Each pocket, after being filled with iron oxide, is subjected to high pressure, so that it becomes practically integral with the supporting grid.

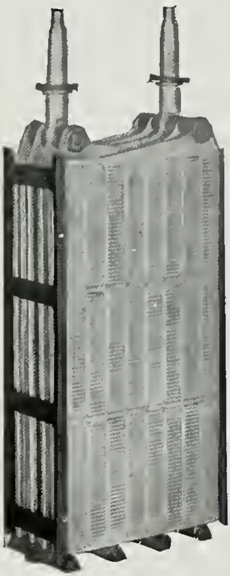


Fig. 14.—Assembled positive and negative plates.

"The positive plate consists of two rows of round rods or pencils, 30 in number, held in vertical position by a steel supporting frame. The perforated tubes into which the nickel active material is loaded are made of nickel-plated steel. These tubes are put together with eight steel rings."

The plates consist of iron oxide for the negative and nickel hydrate for the positive plate acted on by a solution of caustic potash in pure water, which is the electrolyte. The cells are assembled in the usual manner, a positive and a negative plate alternately, there being always one more negative plate than positive. The plates of each sign are connected to a nickel-steel rod and kept the proper distance apart by washers and nuts which hold them firmly in position. Altogether the cells when complete are of most substantial mechanism with nothing to go wrong with them, no buckling of plates, no fear of short-circuiting doing damage, for the battery may be short-circuited and discharged at once without injury to the plates. The battery is kept in order by simply replenishing with pure water when necessary, and charging and discharging may be done almost indefinitely without fear of the plates being used up, as in the case with the ordinary lead-plate cells.

The cells to form a battery are connected in series, five cells of the type described will work a dental engine of 6 volts winding for a very long time, revolving at a speed of from 1000 to 3000 revolutions per minute. There are no

fumes from the electrolyte, so that the battery may be placed in a neat hardwood case and kept in the surgery in close promixity to the engine.

Arrangement of Cells.—The E. M. F. of cells has been shown to depend on the dissimilarity of the plates, the conductivity of the electrolyte, the area and proximity of the plates and the internal resistance set up by polarization within the cell; the size of the cell has no effect on the E. M. F. of the cell, a small Leclanché cell will have almost the same potential as a large one; with the increase of size (so long as the plates are of the same nature) the internal resistance (r) is increased, so that the output of current strength is about the same.

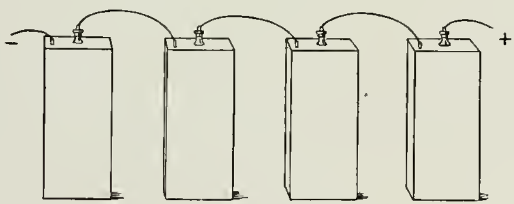


FIG. 15.—Cells in series.

CELLS IN SERIES.—The E. M. F. of one Leclanché cell is about 1.47 volts, which when resistance is taken into account produces a current strength quite inadequate for therapeutic purposes, but this form of cell has been shown to be one of the most useful for producing current for dental ionic-medication; in order, therefore, to increase the current strength a number of cells are connected in *series*, that is, the zinc of the first cell is connected with the carbon of the second and so on till all are connected, that will leave the terminal carbon at one end free and the last zinc at the other end free.

The potential of the cell is from the zinc to the carbon within the cell, therefore at the terminal the flow of current is + at the carbon and − at the zinc.

According to Ohm's law, if each of these cells has an

E. M. F. of 1.47 volts, by collecting 6 of them in series the E. M. F. is increased to nearly 9 volts.

$$1.47 \text{ volts} \times 6 = 8.82 \text{ volts}$$

and three times that number of cells connected in the same way will give about

$$1.47 \text{ volts} \times 6 \times 3 = 26.42 \text{ volts.}$$

The voltage of a cell or collection of cells is simply the electro-motive force. What most concerns us is the current strength which these cells will produce, and to find this the internal resistance of the cells and external resistance of the circuit must be calculated. The resistance of a Leclanché cell varies. When the circuit is first closed it is stronger than after it has been closed for some time because, as we have seen, polarization takes place faster than depolarization, but say it is on an average 2 ohms and the external resistance of the circuit 1 ohm, the current strength (c) of one Leclanché cell would be worked out by Ohm's law.

$$C = \frac{1.47 \text{ volts}}{R1 + r2} = \frac{1.47}{3} = 0.49 \text{ ampère} = 490 \text{ ma.}$$

Now if we take 18 cells in series and consider the resistance (R) and internal resistance (r) we shall find that the resistance has a very marked effect on the current strength, for instead of the current strength being 18 times as great it is only raised not quite twice as much, thus

$$C = \frac{1.47 \text{ volts} \times 18 \text{ cells}}{R1 + (r2 \times 18)} = \frac{26.42 \text{ volts}}{1 + 36 \text{ ohms}} = 0.714 \text{ amp.} = 714 \text{ ma.}$$

It may be taken that this output of 714 ma. current strength is fairly accurate so far as 18 Leclanché cells are concerned; this is about the number of these cells which will constitute a useful battery for ionic medication for

all dental purposes, the full current obtainable from such a battery will of course be more powerful than it is possible to use in the mouth of a patient, but the current weakens after the battery has been in use for a time and it is best to have a reserve of current strength; it is essential to have it controlled by a finely graded rheostat in circuit, through which the current must pass before reaching the patient. The resistance of the body must now be taken into consideration. If a milliampèremeter be connected in circuit with the current flowing from the terminal of the battery, when the circuit is closed without the resistance of the body in circuit but with nearly all the resistance of the rheostat in use, the milliampèremeter needle will be violently deflected 5 or 10 milliampères, the resistance of the wire leads being only one or two ohms; but a very different result will be observed if the resistance of a patient be placed in the circuit. Take for instance a patient having a resistance of 2000 ohms, a considerable amount of current will be required from the battery to register two or three ma. on the milliampèremeter dial. According to Ohm's

$$C = \frac{1.47 \text{ volts} \times 18 \text{ cells}}{R2000 + (r2 \times 18)} = \frac{26.42 \text{ volts}}{2000 + 36 \text{ ohms}} = 0.012 \text{ amp.} = 12 \text{ ma.}$$

law 12 ma. will then be the greatest amount of current strength which will be available from a battery of 18 cells with the resistance of a patient of 2000 ohms in series. This, as has been said, must be controlled by a rheostat which is really resistance placed between the battery and the patient to regulate the output of current strength, so that instead of the full 12 ma. passing, only 1 or 2 ma. pass according to the requirements.

To summarize, it has been shown that 18 Lechanché cells connected in series produce an electro-motive force of about 26 volts and a maximum current strength of about 714 ma. That with the resistance of the body of 2000 ohms in series the maximum current strength is about 12 ma. That the maximum current strength of one cell is about 490 ma.,

which is only slightly increased to 714 ma. by connecting 18 cells in series, showing that the E. M. F. is added together while their remains almost the same. The current which one cell will force through a large resistance will be much less than the amount which 18 cells will force through a similar resistance, although without any external resistance the C is about the same, hence the necessity for a number of cells in a battery which is intended for use with the body as resistance; the pressure, potential or E. M. F. must be of proportions great enough to overcome the resistance met in circuit.

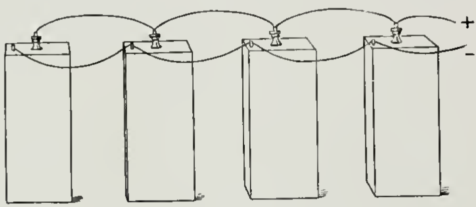


Fig. 16.—Cells in parallel.

Cells in Parallel.—To connect cells in parallel all the terminals of one sign are connected together with one wire to form one pole of the battery and all the other terminals are connected to form the other pole; by this arrangement the collection of cells act like one cell, the internal resistance, however, is considerably reduced, so that a greater maximum current is obtainable. This arrangement is therefore only of use when the resistance of the external circuit is very low (and its chief use in medical and dental work is for heating cauteries where low E. M. F. and a high current is required).

Cells are connected in parallel when a large current strength is required such as for cautery. To get the greatest amount of current strength the choice of cells should be those with the least internal resistance, so that for this purpose Leclanché cells are least serviceable. The bichromate cells and Grove's cells are useful because the E. M. F. of these cells is greater, owing to the nature of the electro-

lyte, the proximity of the plates, and the area of the plates. The E. M. F. of a bichromate cell is about 2 volts with an internal resistance of about 1 ohm, one of these cells will produce considerable current strength for cautery or light, but if six are arranged in parallel the current strength is materially increased. If we add *two* ohms for the external resistance of the cautery wires. according to Ohm's law the current strength can be calculated:

$$C = \frac{2 \text{ volts} \times 6 \text{ cells}}{R2 + r\frac{1}{6}} = \frac{12}{2\frac{1}{6}} = 5.5 \text{ ampères.}$$

If one such cell be tried we should have a current by the same calculation:

$$C = \frac{2 \text{ volts}}{R2 + 1 \text{ ohm}} = \frac{2}{3} = 0.6 \text{ ampère}$$

which would be insufficient to heat a cautery loop or light a small lamp.

Thus it is seen that by adding cells in parallel the E. M. F. remains practically the same as one cell but the current strength is greatly increased.

Accumulators for cautery work are better than voltaic cells, their internal resistance being very low.

Cells in Multiple Arc.—This is another method of connecting cells which has the effect of reducing the internal resistance and increasing the current strength. One way of arranging cells by this method is as follows: take six cells and connect three together in series, and the other three also in series, then join the positive pole of each collection of three to form one pole, and the negative pole of each to form the other pole; the effect of this compound connection will be to double the size of the cells and to halve their number. This can be shown by calculating as before (take for example the bichromate cell with E. M. F. of 2 volts and internal resistance of 1 ohm and say the external resistance is 0.5 ohm). The E. M. F. would be that of three cells ($3 \times 2 = 6$ volts);

the internal resistance would be that of three cells of double the size (1 ohm $\times$ 3 $\div$ 2 = 1.5); therefore

$$C = \frac{E}{R + r} \times \frac{6}{R + r \times 6} = \frac{6 \times 2}{1 + 0.5 \times 6} = \frac{12}{9} = 1.3 \text{ ampères.}$$

Another variation of the compound connection of cells consists in collecting each group, say 3 cells in parallel and then these two groups in series. This will also reduce the internal resistance and therefore produce a greater current strength.

The arrangement of galvanic cells in series and in parallel have a useful place in electro-therapeutics, especially where it is necessary to take about instruments to work away from the surgery or where an alternating current circuit is supplied by the mains; but in dental practice where nearly all work is done in the surgery, batteries are nearly entirely superseded by the use of current from the main, where this is continuous, which can be controlled and regulated by switchboards from which the current can be obtained in every conceivable form for every requirement. Alternating current mains can be used but they necessitate a motor-dynamo to convert the current into continuous.

The battery of cells in series, however, is preferred by many who use a continuous current for ionization, and the advantage undoubtedly is that it is impossible to obtain a severe shock from it.

Density.—We have seen that the distribution of the current on a charged conductor is on its surface, and that if the surface is spherical the distribution is all over that surface evenly, but if it be pointed the density is greatest at the point. So, too, if it be knife-edged the edges will display greater density, whereas the flat surfaces are less charged. These facts have an important bearing on the practical use of the current. In the construction of electrodes, the purpose for which they are required and the manner in which they are to be applied are considerations which should be carefully thought out with regard to the density

of the current likely to be produced by the shape, size, and diameter of the conductor. If it is required to pass a current of 25 ma. into the body, a flat electrode of 5 cm. diameter would be twice as painful to the patient as one 10 cm. in diameter, because the density in 5 cm. area would be so much greater. So, too, a fine-pointed conductor will intensify the current at the point, which will be painful even with a current strength of 2 ma., whereas a conductor which is round and 5 mm. in diameter would not be felt at all with the same current strength. Also a flat, knife-like conductor will intensify the current at the edges while the flat surfaces will have a less density, but if the cross-section be increased and the edges rounded the density will be diminished, being more evenly distributed over the whole surface.

Taking these points into consideration it becomes possible to use more current, say, for instance, in a pyorrhea pocket without discomfort to the patient, or on the other hand, to produce perfect sterilization in the root of a dead tooth by introducing a very fine-pointed conductor, a dead tooth having little sensation except the conductor reaches the apex. Density then has to be considered for the comfort of the patient in the efficient use of the current especially in mucous or periodontal membrane; one of the important factors in ionic medication is: the greater the current strength that is possible to be used without pain, the more penetrating will the medication be, and in order to obtain this it is necessary carefully to consider the area and shape of the electrode which is to convey the current to the parts. It is often difficult to use an electrode large enough to diminish the density sufficiently to cause no discomfort when 4 or 5 ma. is the current strength for ionization of affections about the roots of live teeth or the gingival margin.

CHAPTER IV.

MAGNETIC FIELD, DYNAMO CURRENTS AND BATTERIES.

Induced Currents—Self-induction—Induction Coil—Secondary Coil—Continuous Current — Alternating Current — Transformers — Batteries — Home-made Battery—Cautery Battery—Accumulator Battery.

When a magnet is brought in close proximity to iron filings it attracts the filings and they cling to its surface. If the filings are placed on paper and the magnet placed under the paper and the paper slightly tapped the filings will be observed to arrange themselves in definite lines and curves. This indicates that for some distance around the magnetized iron there is a space or field which is permeated with the influence or force of the magnetism; this field is termed the magnetic field. It exists about all magnets, and experiments have been made to prove that the force created in this field takes certain lines and curves. In a bar magnet for instance, the one end is north pole and the other south pole; if it is balanced on a pivot in the centre, which is the equator or neutral zone of the magnet, the north pole will swing to the north as any ordinary pocket compass does. From the ends of the magnet the magnetic force radiates in curves in the direction from one pole to the other, there being a considerable space about the magnet which is the magnetic field. The strength of the force in a bar magnet is greater at each end. In a curved magnet, on the other hand, the greatest force is exerted between the two poles from their nearest point.

This magnetic force which permeates the field about the magnet is conducted by the air, but air has been found

to be a poor conductor of magnetism, whereas iron is a good conductor and if the magnet is strong enough iron brought in contact with it will itself become magnetized to some degree.

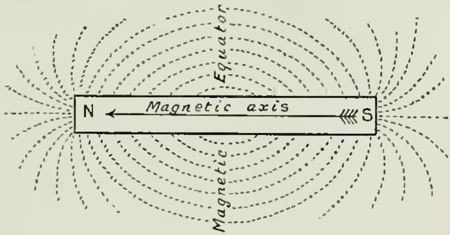


FIG. 17.—Lines of force of magnetic field.

A temporary magnet is made by winding insulated copper wire around an ordinary piece of soft iron bent in the shape of a horseshoe and by passing an electric current through the wire. As the wire does not touch the iron it is evident that the magnetism which is imparted to the iron is

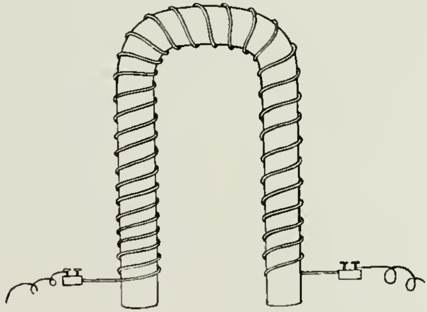


FIG. 18.—Electro-magnet.

obtained from a magnetic field about the current-conducting wire. This magnetic field exists around all wires conducting electric current and the force of the field is intensified by the curving of a wire (making a spiral of it, as by winding stiff

copper wire around a lead-pencil and removing the pencil), and also by the intensity of the current passed through the wire; the field is also stronger when the iron is placed in it.

A magnet made by passing current through wire encircling a piece of soft iron is only magnetic so long as the current is passing, it is a temporary magnet.

Sir Oliver Lodge points out that the magnetic field about a current-conducting wire exerts force in the field exactly similar to force about a magnet, and he describes it as electricity in rotations; many experiments have been performed with the ordinary compass-like magnet in a magnetic field to show the rotatory action of the current in a magnetic field. If a magnetic compass be suspended in the air it will point north and south, but if a wire conveying current from any electrical source be brought parallel above the compass so that it also runs north and south with the positive and negative running from the south to the north, when the wire approaches the compass near enough to bring it into the magnetic field, the N-point of the compass will deflect to the west, showing that the force of the field is outward and backward, rotatory, in the same direction as the lines described about an ordinary magnet. On this principle of the force of the magnetic field, galvanometers are constructed to measure the force of current strength.

The energy derived from the field of force about an insulated conductor of current by which temporary magnets are created is termed electro-magnet, and as the magnetism so derived ceases as soon as the current ceases, the principle is applied in the construction of many electrical appliances in which rise and sudden fall of energy operates in mechanical devices.

An electro-magnet has been devised for use with the ordinary street current with a lamp in circuit as a reducer of the current, which when applied to the cavity of a tooth or near the orifice of a root canal, in which is a broken drill or any piece of steel, if the metal is loose, will extract it with ease by the powerful electro-magnetic force. Magnetic force is not conducted in the same way that current is, so that

the energy is not felt by a patient. Electro-magnets have been constructed of enormous power, capable of raising tons of metal. The strength of electro-magnetic field depends on the current strength which is used in creating it.

Induced Currents.—From the foregoing it has been shown that there is a field of magnetic force about a wire conducting current. Faraday discovered that if another wire was brought within the influence of this field, it had the power of inducing current at the moment of turning on and turning off the current (that is, at the make and break of circuit); also if the current strength be varied or changed in direction. The current so produced in the adjoining wire is momentary and occurs at the make or break or change of potential. Also, the direction of the induced current varies with the make and break of the circuit in the primary or current-conducting wire; when the current is turned on in the first wire the momentary induced current in the second wire flows in the opposite direction, and when the current is turned off the current is again induced in the second but in the same direction as the primary wire. The same phenomenon of induction takes place when the current is increased in the primary wire, the induced current flows in the secondary wire in the opposite direction, but when it is reduced in strength the induced current flows in the same direction as the primary wire. This induction of current in a magnetic field about a wire conducting current is due to the expansion and contraction of the magnetic field of force. The above is the simplest form of induction that can be imagined and may be practically illustrated in the adjoining sketches of two parallel wires, the one conveying current and the other inducting current, the arrows showing the direction of the induced current at the moment of make or break of circuit.

While the current is flowing uniformly in the primary circuit no induced current is formed; it is only at the instant of make and break or increase and decrease of potential that induction takes place.

The magnetic force in the field about an electric wire

is in the direction at right angles to the direction of flow of current in the wire, precisely in the same manner as the

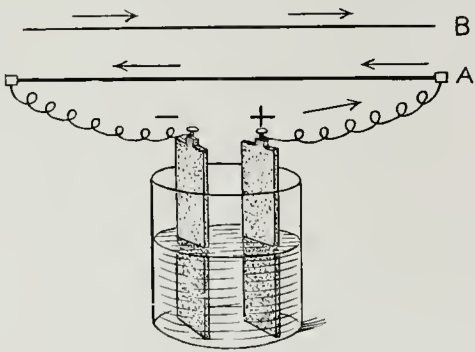


FIG. 19.—*A*, primary current at make; *B*, induced current at make.

field about a magnet, forming, as it were, concentric circles about the wire; when the wire is bent in the shape of a coil the magnetic field of force is increased, but the resistance

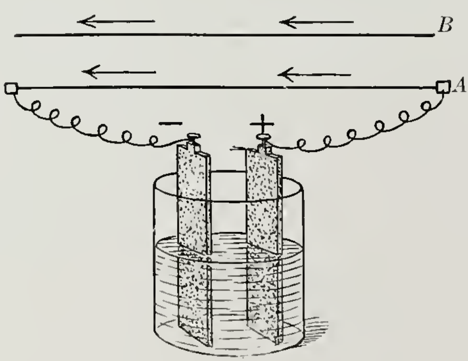


FIG. 20.—*A*, direction of current before break; *B*, induced current at break.

is also increased, so the strength of the magnetic field will depend on the strength of the current and will be proportional

to the current and the field of force. The introduction of an iron core will also, as has been shown, increase the strength of the field.

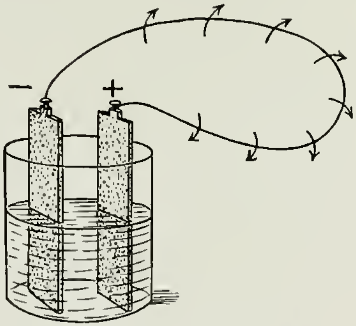


FIG. 21.—Field of force about a wire.

If a secondary coil be introduced into the magnetic field of a stationary primary coil and be moved away or toward it, current is exerted in the secondary coil; this effect is produced by the magnetic circles of force about

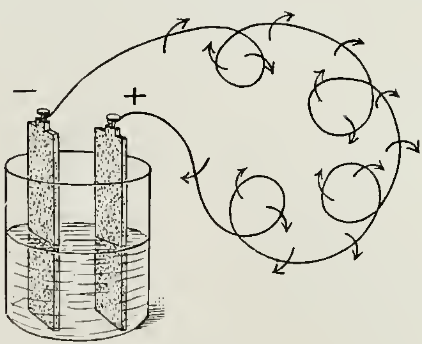


FIG. 22.—Field of force in a coil.

the active coil being cut into by the circles of force in the induced current of the other coil. This principle of induction is carried out in the production of current by

dynamos in which armatures are constructed to cut the lines of force from the field magnets by their motion.

Self-induction.—This takes place in a simple coil or primary wire and is the effect of passing a current through a coil by which a magnetic field is set up about the conducting wire of the coil and a reaction of E. M. F. is set up in the conducting wire itself at the make and break of the circuit; at the make of the circuit the current is resisted by the induced current in the magnetic field in an opposite direction, and at break of the circuit the induced current is momentarily conducted by the conducting coil in the same direction as the current in circuit. In other words, each coil induces a current in the next. If a current from a battery be passed through a single coil and the terminals be so arranged that there will be a small gap over which a spark can pass, on breaking the circuit a spark will be observed at the spark gap of a size large enough to ignite an ordinary gas jet. The current which produces this spark is the self-induced current in the coil. If the wires from the same battery do not include a coil in circuit, the breaking of the current with a similar spark gap will produce no visible spark. The strength of the self-induced current is greatly magnified when the magnetic field about the coil is increased, as when the current is supplied from an alternating dynamo and still further increased when an iron core be introduced into the centre of the coil on the principle of an induction coil. The extra resistance introduced into the coil by the strong magnetic field produced by the alternating current on the magnetism about the iron core, reinforces the self-induced current and on breaking the current a large spark is produced according to the strength of the current employed; moreover, the strength of the self-induced current will be increased or diminished by the number of turns in the coil, the larger the number of turns in the coil the greater will be the magnetic field, and the stronger the self-induced current.

The resistance set up in such a coil by the self-induction current is very much greater than the ordinary resistance of the same wire not formed in a Solenoid, as the hollow

spiral of a self-induction coil is termed; the resistance only occurs when the current begins to flow or increases its strength, a steady current meets with no resistance from self-induction.

The Induction Coil.—This is probably one of the commonest and best-known electrical devices in use for medical purposes. So far it has been little used in dental treatment and it is hard to conceive many uses to which it can be directly applied. The principle of the induction coil should, however, be studied, for it enters into the construction of numerous electrical devices, which are of importance to dental science and has a direct bearing on them, such as the *x*-ray and high-frequency coils. It consists of a primary coil, a secondary coil, an interrupter, with sometimes a condensor.

A simple form of coil consists of a core of iron or bundles of iron wire around which is wound the primary coil consisting of a number of turns of wire which is insulated with silk wound around it. The core must be carefully insulated from the primary coil. The coil is connected with a battery and conveys the primary current. The interrupter is placed opposite the core and is a vibrating spring with a metallic head which affords the spring momentum when set in motion. A stationary adjustable screw with a platinum point is fixed at the middle of the spring. The spring and primary coil are connected to one pole of the battery and the adjustable screw is connected to the other pole. When the current is passed through the coil the magnetic field which is set up about the coil converts the iron core into an electro-magnet which attracts the metal head of the spring and breaks the contact at the adjustable screw; contact being broken. the current at that instant ceases to flow in the coil and the core loses its magnetism, therefore the metal head of the spring swings away from the core, and in doing so by its own momentum once more establishes contact by touching the metal point of the screw. This process repeats itself in rapid succession, making and breaking the contact and in this way induced

currents are established and increased in the magnetic field about the primary coil which also intensifies the electromagnetic force of the core. This simple form of induction coil does not admit of any regulating of vibratory current set up by make and break, and the force of the induced current established in the magnetic field about the core will depend on the strength of the battery which is producing the primary current. The current from two Leclanché cells in such a coil will often induce a maximum vibratory current greater than one can bear when the terminals are held in the hands. The maximum E. M. F. produced in both coils is higher than the battery supplying the energy to the apparatus.

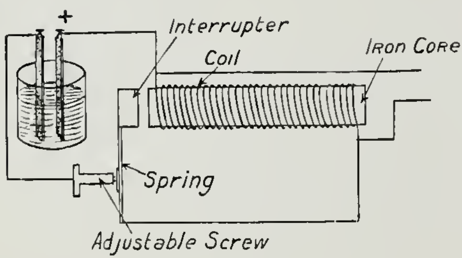


Fig. 23.—Induction coil.

There are many devices in the arrangement of the coil and the core by which the current strength can be regulated. This is done by introducing resistance into the circuit to control the current strength in such manner that it can be varied, or by resistance introduced into the primary coil which can be adjusted to vary the induced current. This latter is usually done by having a movable adjustable core or a movable secondary coil, or a brass tube to slide over the core, or a combination of these may be used.

A simple form of induction coil in which the current strength can be regulated consists of a primary coil as already described, but a stationary magnet is introduced instead of the core. The current from a battery passes to

a stationary upright to which is attached a spring which is in contact with an adjustable screw, from the screw it passes to the primary coil which is wound on a bobbin, the return wire is wound around a stationary core fixed under the spring and from this it is taken to the other pole of the battery; this second core then serves to interrupt the current in the same way as described above.

Secondary Coil.—A secondary coil is wound with a great number of turns of insulated wire, and slides over the main primary coil so that it is in the magnetic field and can be passed completely over the primary coil or drawn away to cover only a very small part of the end of it. When the circuit is closed the current acts on the coil as already described and the strength is varied by moving the sliding secondary coil. The secondary coil becomes charged with induced current which on make is in the same direction and on break is in the opposite direction to the flow of the primary current; by sliding the secondary coil over the primary, or pulling it away, the induced current is varied and the strength of the vibratory current from the coil is increased or decreased by the regulation of the intensity of the magnetic field and induced current set up about the coil.

The arrangements of the wires of an induction coil are best understood by diagram; by following out the lettering of the figures which is the same in both diagrams, the course of the current and its action on the secondary coil and the magnet are easily comprehended. The diagrams are from Lewis Jones' book. "One pole of the battery is connected to the coil at *A*. The current then passes by the adjusting screw *B*, the vibrator *H*, and the support *K*, to the magnet *D*, which actuates the contact-breaker. After traversing this the circuit gives off a branch to the binding screw *P*, and is continued to the primary coil *EE*, the return wire from which again gives off a branch to the secondary binding screw at *P*, and is then continued to the other pole of the battery. The two binding screws at *P* are thus in connection with the two ends of the primary coil, and by means of electrodes attached to them the patient may be treated with

the primary current of this coil. The secondary coil *F* is wound on a separate hollow bobbin and has its terminals at *S*. This bobbin is made to slide like a sledge on guides, so that

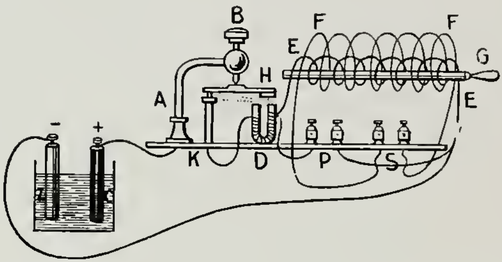


Fig. 24.—Arrangement of wires of an induction coil.

it can be made to approach or recede from the primary coil. At *G* a handle is seen attached to the iron core which can slide in and out of the primary coil and so further modify the electro-motive force induced in the primary and secondary coils by varying the strength of their magnetic field."

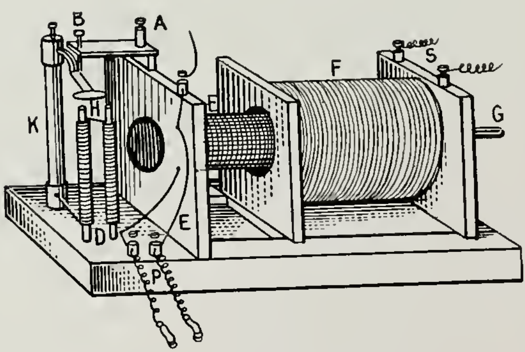


Fig. 25.—Induction coil.

It can be readily seen from these diagrams that when the circuit is closed the current passes through the coil and returns by way of the magnet and renders it electro-

magnetic, and it then attracts the vibrator which causes the break in the current, the magnet at that instant loses its electro-magnetic force and releases the vibrator which springs back into contact with the adjusting screw, and once more closes the circuit. This is repeated in rapid succession. The adjusting of the screw and the sliding in and out of the secondary coil regulates the frequency and the strength of the vibrations.

The secondary coil is generally constructed of many thousands of turns of wire according to the strength of E. M. F. desired, the more turns the greater the induced electro-motive force; the resistance of so many turns of wire is overcome by the great increase in the induced E. M. F. The magnetic field and induced current are increased quite out of proportion to the resistance by the increasing of the number of turns in the coil.

DYNAMO CURRENTS.

Continuous Current.—In speaking of the continuous current it should be remembered that the current from dynamos is not truly continuous, being really a series of overlapping waves, but these are, in a good machine, so slight that it is usually known as continuous; strictly speaking, continuous current is obtained from batteries.

The continuous current from the main, which constitutes a large proportion of the electric supply in commerce, is made by converting mechanical power into electrical power by means of the *Dynamo*.

The Dynamo.—The principal parts of a dynamo are the field magnet, the armature, and the commutator or collecting brushes. The field magnet is built into the dynamo machine and consists of a sort of iron core, built up of a series of thin plates insulated from one another to prevent "eddy currents," wound with a coil around it which receives current from the armature to make it electro-magnetic when the machine is working, on the principle of the induction coil; it also becomes a permanent magnet to an

extent sufficient to start the dynamo with a few turns of the armature. It is so constructed that the armature is received into two hollowed-out surfaces of the opposing poles of the magnet, the space between the magnet and the armature becomes a powerful magnetic field when the dynamo is working.

The poles of this electro-magnet are permanently set north and south.

The armature is constructed in some dynamos of two insulated metallic rings on a shaft which fits into the hollowed space between the poles of the field magnet so that a small space is left between it and the electro-magnet; it is also often constructed of an iron core upon which is wound insulated conductors so contrived as to fill the space between the magnetic poles without touching the magnet, as shown in Fig. 26.

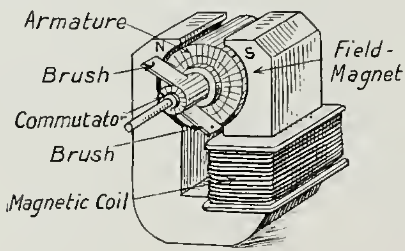


Fig. 26.—Plan of dynamo.

On a continuous current dynamo there is a *commutator* which consists of a number of copper bars insulated from each other and mounted in the form of a cylinder through which the insulated shaft passes, the number of bars correspond to the number of coils in the armature to which they are also attached.

The Collecting Brushes consist of two copper gauze brushes or carbon blocks which are in contact with the commutator, set opposite one another on the commutator; when the dynamo is in motion the segments of the commutator pass in

rapid succession under the brushes which collect the current generated in the machine and conduct it from the dynamo by wire connections attached to the brushes. The commutator converts the alternating current set up by the action of rotating the insulated conductor in the magnetic field into a continuous current.

The current which is generated in the armature passes into the external circuit and also induces a current in the coil around the electro-magnet, rendering it electro-magnetic when the dynamo is in motion.

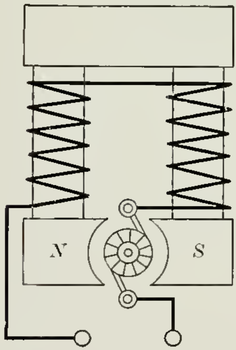


Fig. 27.—Plan of series-wound action.

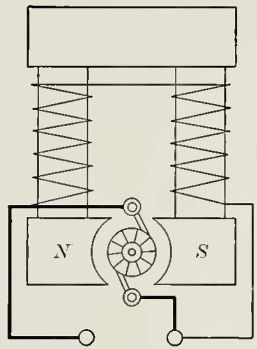


Fig. 28.—Plan of shunt-wound action.

There are two forms of dynamo winding, the series-wound and the shunt-wound dynamo.

In the *series*-wound machine the current passes from one brush through the field-magnet coil, then through the external circuit back to the other brush.

In the *shunt*-wound dynamo the current passes in two distinct loops, the first from one brush around the field magnet and back to the other brush, the second, which is the stronger current, passes through the external circuit only; these two are separate currents connected in parallel. Shunt-wound motors are the type usually used in dental engines, lathes, and motor transformers.

The dynamo is a reversible machine, that is, if it receives current from another source it will itself become a motor transmitting force but in the reverse direction. Take, for example, a small dynamo such as is sometimes used to generate current to charge accumulators, which is usually driven by some form of mechanical power like a water or gas engine, if the driving power is disconnected and the current from the charged accumulators switched on, the dynamo will work as a motor but in reverse direction as long as current is supplied to it; in others words, it converts mechanical power into electric current, but if supplied with current from another source it becomes a motor-transmitting power.

Alternating Current.—This current from dynamos is one, as indicated by the term, which alternates. The flow of current rises to maximum in one direction then falls to zero and rises to maximum in the opposite direction; the time which elapses between the rise in one direction from zero to maximum and back to zero is called a semicycle, and the time which elapses from the rise in the opposite direction from zero to maximum and back to zero is the other semicycle, so that the cycle is completed in the time occupied from the rise in one direction to the commencement of the rise again in the same direction. These semicycles correspond respectively with the passage of the coil through the north and south poles of the electro-magnet. The time occupied by a cycle in a dynamo therefore depends on the rate of the revolutions; in some machines the cycles are regulated at 60 cycles per second and are perfectly uniform in number of alternations. The change from one direction to another in an alternating machine occupies an exceeding short space of time, as is shown by the foregoing, and in well-made dynamos is quite regular.

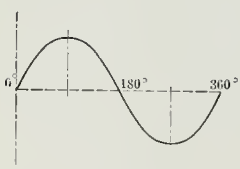


FIG. 29.—Double semicurve.

The current from an alternating machine is often spoken of as a sinusoidal current, indicating the curves which would

be marked out by an instrument made to register the sine curve.

Suitable transformers are required for whatever the source of current to convert the current into a smooth wave-like alternating current as used in medical work, and is much less painful and more effective for many porposes than the sharp, jerky current of a faradic coil. The alternating current from the main is the only kind supplied by many installations in country towns for lighting purposes; it is cheaper to install because of the ease and simplicity with which it is transformed from one potential to another, and also the copper cables used for the mains are much smaller than for continuous current. The current passes through those cables at enormous volt pressure and is transformed when installed, into 100 or 110 volts by a transformer which reduces the voltáge and increases the ampèrage.

The current from alternating dynamos cannot be used as such for charging accumulators, ionic medication, or cataphoresis, but as has been stated is used for driving motors, heating cauteries, lighting, rotating high-tension transformers for *x*-rays, and for high frequency.

Transformers.—A continuous current can be transformed into alternating by means of a motor working as a dynamo (motor-dynamo) and the alternating can be made continuous by a similar instrument. The volts can be reduced and the ampères increased, or *vice versa*. It has been shown that in the induction coil the electro-motive force of the secondary coil depends on the ratio of turns in the secondary coil to the primary; if the secondary coil has four times the number of turns, the E. M. F. will be approximately four times that of the primary, and if it has one quarter the number of turns that the primary has, the E. M. F. will be about one-fourth that of the primary. At the same time the current strength (the ampères) will be affected to the same extent in the opposite direction; a high E. M. F. by this arrangement can produce a very low current strength or a low E. M. F. a very high ampèrage. A transformer can be designed to produce a current strength of one ampère at 100

volts or 100 ampères at one volt, or can be made to convert one into the other.

An alternating current from the main can be transformed by induction into one of low voltage and high ampèrage; for example 2000 volts and one ampère can be transformed into 100 volts and 20 ampères.

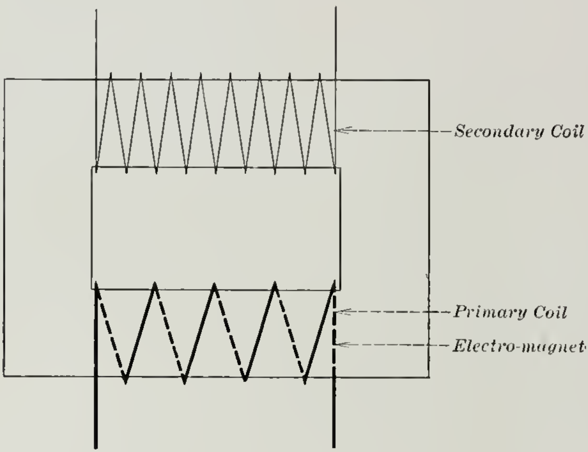


Fig. 30.—Alternating current transformer.

As shown in Fig. 30, the transformer is in the form of an induction coil, the principle is the same, but this is a closed-circuit transformer and a much more efficient machine than the induction coil. It consists of an iron core, which is the electro-magnet, a primary coil through which circulates the alternating current and a secondary coil which is in the magnetic field and is not wound around the primary but around a different part of the magnet and receives the induced current. The E. M. F. induced in the secondary coil can be regulated by the turns in the coil in ratio to those in the primary as has been explained elsewhere. Transformers for alternating currents are especially useful for cautery, mouth lamps, hot air, root driers, or syringe.

The principle, as explained, of reducing the volts and increasing the ampères places the current for these purposes entirely in control. By placing a regulating rheostat in the secondary circuit the current which has been transformed may be regulated to suit the kind of cautery or lamp or other instrument which it is proposed to use, by

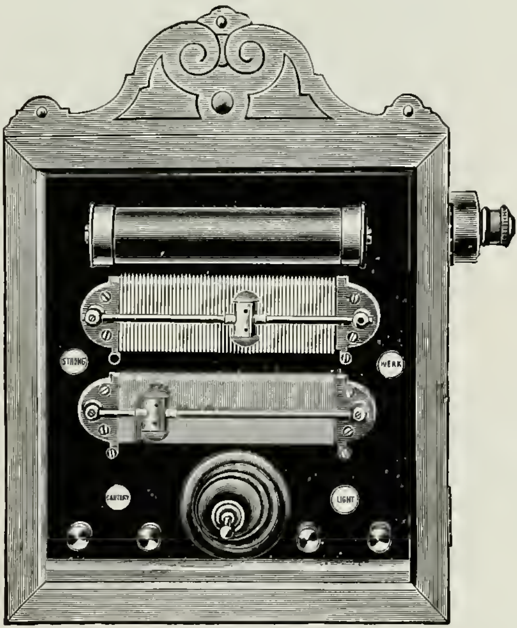


FIG. 31.—Transformer.

varying the resistance. The rheostat can be regulated to heat a cautery loop requiring 2 ampères or be adjusted to increase the current materially to heat a much larger loop.

Transformers are also used for converting the alternating current into high voltage and small ampèrage for high-frequency appliances. They are especially adapted for this purpose, for the current being alternating, can be

used from the main without interrupters. For x-ray work an alternating current when transformed must be made unidirectional before it can be used in the tubes.

BATTERIES.

The construction of galvanic cells, their chemical action during the production of current, and the methods of connecting them to obtain various current strength has already been described. It has been pointed out that Leclanché cells are the most practical and most lasting form of voltaic cell, because no change takes place within the cell when the circuit is open.

There are many forms of batteries from which a continuous current is obtained for most kinds of dental electrotherapeutic work.

A useful battery consists of 18 or 24 small Leclanché dry cells which just fit into an oak box made for the purpose, the cells are connected in series and the current is controlled by a crank cell collector by which one or the whole battery of cells can be turned on by switching around the spring of the crank onto the studs of the collector. The current passes from the controller to a sliding shunt rheostat and from this to a milliampèremeter from which it goes to one of the terminals of the battery, the other terminal is set parallel with the former and to these the conducting wires are attached for using the current.

The battery also is provided with a current reverser, a very necessary and convenient appliance for ionization. A well-fitting cover keeps the battery free from dust, and a drawer in the side to keep electrodes and wires handy for use. In using the battery all the cells should be switched on and the current regulated through the rheostat, which is finely graded and turns on the current very gradually by sliding the contact shunt along the metal bar.

A battery should not be used for ionization without a rheostat, because the cell selector alone switches on too much current at a time, with the consequence that a painful shock

is experienced when each cell is added to the circuit. Most of these batteries are made and sold by instrument makers with only a collector, but a rheostat should be insisted on if good results are desired.

FIG. 32.—Galvanic battery.

The current from a battery of 18 or 24 Leclanché cells works out according to Ohm's law as follows: Presuming the E. M. F. of each cell to be 1.5 volts, which is very nearly correct, and the internal resistance (r) to be 3 ohms, with a patient in circuit of 1500 ohms' resistance (R) the current strength (C) would be

$$C = \frac{\text{E. M. F.}}{\text{R} + \text{r}} = \frac{18 \text{ cells} \times 1.5 \text{ volts}}{\text{R}1500 + (\text{r}3 \times 18)} = 0.017 \text{ ampère} = 17 \text{ ma.}$$

Seventeen milliampères is a great deal more current than is required for ionization of the periodontal membrane, and the E. M. F. from such a battery is ample.

A battery of 24 cells on the same method of calculating will produce:

$$C = \frac{E. M. F.}{R + r} = \frac{24 \times 1.5}{1500 + (3 \times 24)} = 0.022 \text{ ampère} = 22 \text{ ma.}$$

The current from a voltaic cell battery is a continuous and smooth current, much more so than from any working dynamo from which there is a certain amount of pulsation, although this pulsation is not perceptible to a patient when the current is properly controlled by a finely graded rheostat and a lamp in circuit on the switchboard. Some dentists, however, prefer the battery to the switchboard.

Home-made Battery.—A dentist should know how to construct his own battery. This is a simple matter with a slight knowledge of the construction of the parts and the path the current should take. A battery which the author used for a number of years and was one of the most satisfactory he ever possessed was made by himself as follows: Place 24 Lelanché dry cells in a small box, which will just hold that number, connect the cells in series with red covered bell wire, that is, join the zinc of No. 1 cell to the carbon of No. 2 and so on until all are connected, that will leave the first carbon and the last zinc unconnected, to each of these attach a wire two yards long but let the first wire be blue and the last be red to distinguish them. The wire from the first carbon will be the positive pole and the other the negative pole of the battery. Place the box in the left-hand corner of the shelf in the lower portion of the cabinet and bore two holes an inch apart about 6 inches above the cells in the back of the cabinet, through these holes pass the two wires. Get a neat polished board of the same wood as the cabinet made in the form of a shallow tray ($\frac{1}{2}$ inch deep), to fit the side of the cabinet which is nearest to the operator as he stands by his chair; to this board

first assemble a milliampèremeter, shunt rheostat, current reverser, and two screw terminals with the poles marked on them. These all have contact screws which pass through the board to the tray-like surface at the back where the connections with the battery are made with insulated wire in the following manner:

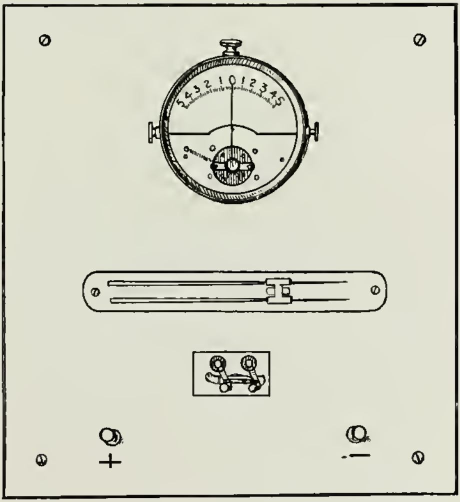


FIG. 33.—Switchboard with parts assembled.

To the — terminal connect the red wire from the battery.

To the distal end of the contact rheostat attach the blue wire, connect the other end of the rheostat with one upright of the milliampèremeter and from the other upright take a wire to the + terminal screw. The battery is now complete but for a current reverser which can easily be included if desired but which makes this description a little more complicated, and has not been included in the description, which it is desired to make as simple as possible. The board, when the several parts are connected up, is screwed onto the side of the cabinet, and the outfit is a fixture from

which the current can be switched on at will. Such a battery will supply current for ionization, gold plating, and many kinds of work for which an ordinary continuous current is desired in dental practice.

The cells last about eighteen months or two years, according to the size. When they are worn out they are easily replaced by new ones at a nominal cost. Leclanché wet cells can be used in the same manner and they last forever with the renewal of the zincs when required, and occasional recharging with sal ammoniac, but they take up more room and are not as clean as the dry cells.

This battery can be made on the same principle and placed in a portable box instead of being stationary as described.

Cautery Battery.—For cautery and light a battery is required which will produce high ampèrage; for this purpose the cells are connected in parallel. Four to six large cells of the acid electrolyte type so arranged that the elements can be lifted out of the chemical electrolyte when the cautery is not required, constitute a lasting and serviceable cautery battery. Cells in parallel act like one large cell with large zinc surface, producing current as if contained in one cell, only the resistance is lessened by having several cells and the current is collected more effectively, the voltage, however, is affected in the reverse, it remains the same as from one cell. This has already been explained.

The heating of the cautery loop depends on the voltage and internal resistance of the battery, and in constructing such a battery this must be very low in order that a very large current may be taken from it. The current strength can be augmented by adding cells in series with each of those in parallel, or by connecting two equal numbers in parallel and then these two groups in series; by this arrangement the current from a number of cells is produced with the resistance reduced as if from cells in series.

Where the main current is installed the cautery from a switchboard is much more satisfactory, but the resistance must be constructed to control large currents.

Accumulator Battery.—For cautery work and lighting small mouth lamps, antrum lamps, and working the dental engine, this form of battery is one of the most useful. The principle of the accumulator cells has already been described. For cautery two to six cells are connected in parallel and they need not be of large size, the cells have an E. M. F. of 2 volts each and the current strength will vary according to the capacity of the cells. When formed into a battery

Fig. 34.—Accumulator battery for cautery

there should be a sliding contact rheostat to turn on the current gradually to suit the size of the cautery or lamp that is being used. Many of the small batteries have a capacity of 50 ampère-hours which under ordinary circumstances will do service in a dental surgery for a long time. The accumulator battery is superior to a chemical cell battery for surgical work or light.

CHAPTER V

BATTERY ACCESSORIES.

Current Collector — Milliampèremeter — Rheostats — Rheophores — Electrodes—Rheostat for Direct Current from the Main—Resistance for Heavy Currents—Alternating Current Transformers—High-frequency Currents.

Current Collector.—It is usual for most continuous current voltaic cell batteries to be constructed with a current collector. The object of the collector is to vary the number of cells to be brought into use at one time to suit the special case or to increase the number of cells or collection of cells by units as required. A battery containing, say, 24 cells may be used with this contrivance so that one or any number of cells are switched into circuit by turning the crank handle of the collector.

The current collector consists of a number of metallic studs arranged in a circle, fitted in a vulcanite plate which covers the cells in the box. The studs are insulated from each other and are connected by wires to the corresponding cells in the battery in regular order as shown in diagram Fig. 35, in which the studs numbered 1 to 8 are connected to the positive pole of cells 1 to 8; the negative pole of cell No. 1 is connected to a separate stud numbered 0, which is connected with the negative terminal of the battery. A movable crank handle from the centre of the circle of studs is made to fit with perfect metallic contact on the tops of the studs over which it can be moved to make contact with any of the studs and lead of current from the cells corresponding in number to the stud in contact. The crank is connected as shown in the diagram with the positive terminal of the battery.

The cells being in series it can be readily seen that by moving the contact metallic crank to a stud, say No. 8, all these cells will be brought into circuit between the terminals marked + and −, and in the same way when the crank is on No. 4 or No. 2 or any stud it brings into the circuit the number of cells corresponding to the number marked against the particular stud on which it rests.

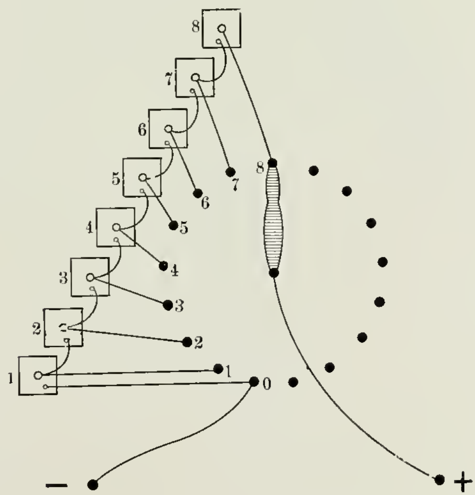


Fig. 35.—Plan of current collector.

In moving the crank from stud No. 1 to No. 2 and so on over all the studs it increases the E. M. F. and current by the amount corresponding to that of each individual cell as the crank moves to each adjoining stud. This increase is too sudden for the comfort of the patient in the treatment of sensitive tissues, such as dentine, pulp, or periodontal membrane.

With this form of current collector the cells which are connected with the studs in the first part of the series are used more frequently and consequently become exhausted

first, leaving the latter part unused or much less used. To obviate this difficulty a more complicated collector has been devised, called the *double collector*, by which any section of the battery may be collected.

Milliampèremeter or Milliammeter.—No battery is complete without a milliampèremeter, which should be connected in the path of the current between the rheostat and the patient. The value of the milliammeter to the operator for determining the current strength can hardly be overestimated, and no one should use the current for dental operations without one. This instrument has been greatly improved of late by the invention of d'Arsonval, who applied the principle of replacing the permanent magnet of the galvanometer by a solenoid which produces a magnetic field when the current is passed through the instrument; by this method the pointer of the needle is made dead beat, thus it does not oscillate when the current is first passed, as is the case in old forms of galvanometer; its movements are controlled by being placed in a magnetic field between the poles of a magnet, delicate hair springs are attached to the needle through which the current passes, the needle deflects gradually from zero, indicating the current strength which is passing, and on returning to zero is kept steady by the adjustment of the springs. The instrument (Fig. 36) works perfectly in all positions, which is an improvement on those which are dependent on earth's magnetisms, and which therefore require to be set in the magnetic medium.

The best instruments are provided with a *shunt*, which is a device for lowering the known resistance of the meter by a known amount without influencing the magnetic field. By connecting the shunt the path of the current is open to a conducting wire which allows one-ninth the resistance and therefore nine times the current strength to pass, thus nine-tenths of the current passes through the shunt while one-tenth passes through the instrument. A second turn will allow ninety-nine times the current strength to pass by contact with a second wire brought into the circuit. The plan of the instrument is shown in Fig. 37. The

lowest current strength is indicated on the dial by 1, increasing up to 5 milliampères. By turning the shunt once the

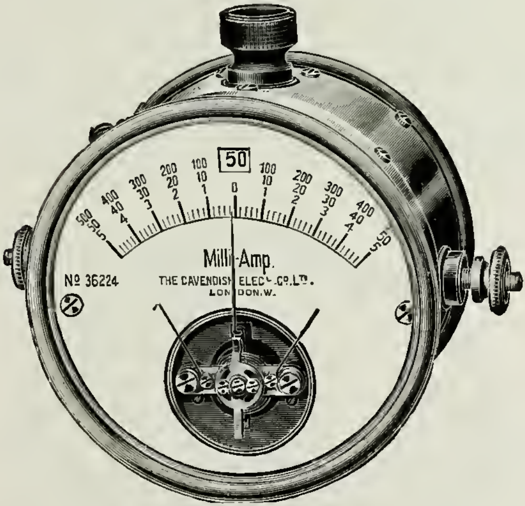


FIG. 36.—Milliammeter.

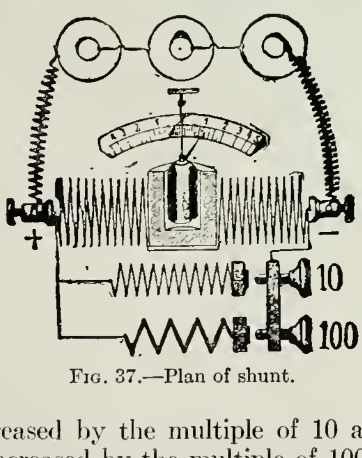


FIG. 37.—Plan of shunt.

current is increased by the multiple of 10 and by turning it twice it is increased by the multiple of 100. In ordinary

dental work it is seldom the first shunt is required and the second never. If the current is required for any other purpose than ionization, such as gold plating for example, where the resistance of the electro-chemical salts in solution is very slight compared to the body, it is best to remove the milliampèremeter and connect the path between the uprights for holding it, with a piece of copper wire, as strong current passed through the instrument tends to stretch the hair springs and to damage the delicate mechanism.

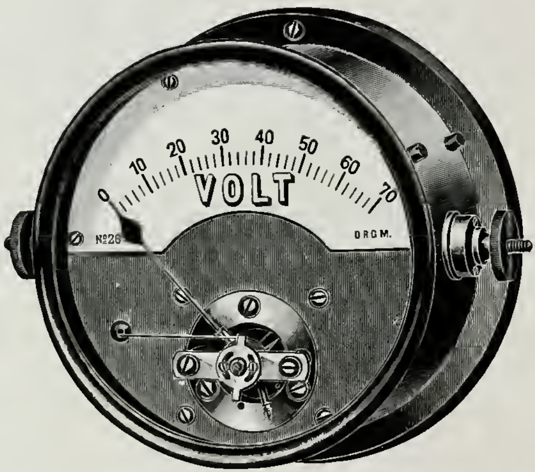


Fig. 38.—Voltmeter.

Ampèremeters and voltmeters are also constructed on the same principle as the d'Arsonval type milliampèremeter, and are used in measuring strong currents such as current from a small dynamo used for charging accumulator battery, and also for testing the voltage of the cells and batteries, or the current passing from a switchboard for ionic medications.

Rheostats.—In addition to the current collector it is necessary in most dental operations to have a finer graduated scale for the increase of the current strength; the

switching on of one cell at a time, each cell of 1.5 volts, increases the current strength too suddenly in operating

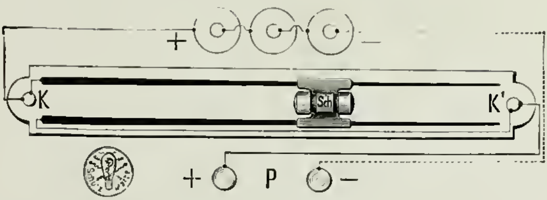


Fig. 39.—Graphite rheostat.

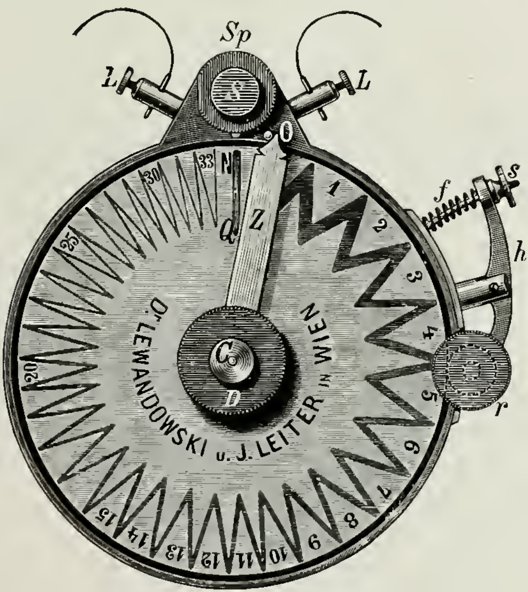


Fig. 40.—Graphite dial rheostat.

on periodontal tissue or on sensitive dentine, the consequence is a painful shock each time the crank of the collector reaches another stud. To obviate this a rheostat should

be placed in circuit between the cell collector and the milliampèremeter, indeed, it is unnecessary to have a current collector when a proper rheostat is installed. A delicate form of rheostat is one of graphite which has a resistance of 1000 to 5000 ohms. The current passes through a graphite pencil with a sliding contact spring which gradually turns on the current by sliding the spring along a bar. By this only a fraction of a milliampère of current is allowed to pass at a time, and the increase is not detected until the current reaches the desired strength. In operating on nerve tissue or sensitive dentine a rheostat of this description is very essential in order to increase the current without considerable discomfort.

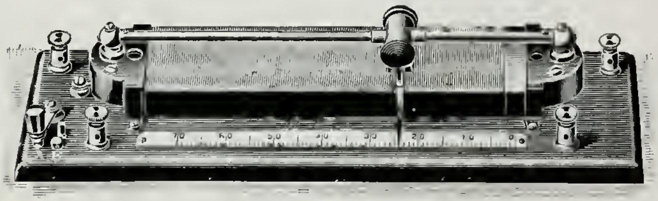


FIG. 41.—Wire resistance.

The most perfect rheostat for resistance of current from voltaic cell battery and switchboard, useful for delicate work on the pulps of teeth or obtaining sensitive tissue, is one shown in Fig. 40. It is constructed of a glass dial which turns on a central pivot, on the outer circle of the dial graphite is impressed into the irregular etchings on the surface of the glass. This is graduated from very fine to coarser receptacles for the graphite, in the manner shown in the figure. The contact is made with mercury, which is let into a slot underneath the dial, and acts as resistance. By turning the glass dial over the mercury in contact with the graphite conductor the very minimum of current strength only is allowed to pass if the dial is slowly turned. The full resistance of this instrument is about 20,000 ohms, decreasing gradually to 20 ohms.

A convenient and effective rheostat for a battery, where no current collector is attached or necessary, consists of a slate core around which is wound many hundred turns of insulated wire, a sliding metallic contact spring is adjusted to move over the coils of wire, making contact with portions of the wire from which the insulation has been removed, in such a manner that contact with each turn of the wire decreases the resistance by the amount of resistance in the length of wire that passes around the slate core, which, in this instance, is about 0.1 volt, and the current strength is very gradually increased. This form of rheostat is largely used on switchboards to reduce the current from the main. It requires careful attention in a damp climate, for, should the wire oxidize, the insulation is liable to become imperfect, and the current brought on in irregular jerks which is uncomfortable to the patients. Should this occur the instrument should be discarded.

Rheophores or Conducting Cords.—Rheophores or conducting cords are made of insulated flexible wire finished off at each end with suitable metallic connecting ends for attachment to the terminals of the battery and electrodes. They should be of sufficient length to give perfect freedom in using the electrodes; two or two and a half yards is a convenient length, and it is best to have two colors, one for the positive terminal and the other for the negative. They are best made of several strands of fine copper wire twisted into a flexible cord which is insulated by cotton covering. Cords of a single wire covered with rubber are sometimes used, but these are liable to break from being frequently wound up and unwound for use, and should a break occur when the current is in use, a painful and alarming shock to the patient occurs, the possibility of which must be carefully guarded against. This is a possible contingency with any conducting cords which should be guarded against by using none but the best quality, and seeing that it is always in good order. A break of the cord takes place most frequently at its junction with the attachment for the terminal or electrode, and if not discovered may lead

to the conclusion that the current has failed, which may not be the case; it is then advisable to test the battery to decide this point.

Electrodes.—These are the conductors which convey the current to the body. They are the terminals which are constructed of some conducting material specially intended for the application of the current to the patient. The active electrode is that which conveys the current to the body, and the indifferent electrode is that by which the circuit is completed.

They consist of all sorts of shapes and sizes constructed to suit the particular purpose for which required. In medical practice these are very numerous; for dental work the indifferent electrode or the one to which the negative pole is connected, should consist of some unoxidizable metal

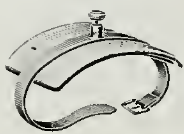


FIG. 42.—Wrist electrode.

(or of carbon) which should always be covered with some material to prevent actual contact of the metal with the body, such as lint or chamois leather or any absorbent material, which must be free from chemical ingredient. Metal should not be used uncovered to apply electricity to the body because it is liable to cause pain and inflict burns or blisters on the surface of the skin, due to the electrolytic action set up at the surface of contact.

The indifferent electrode should consist of a flat piece of metal about two inches in diameter to which is soldered a terminal in the centre for attachment of the conducting cord. It should be covered with a pad of lint which can be readily removed and renewed. A leather strap with a buckle to attach it to the patient's wrist completes the wrist indifferent electrode. It is essential to keep the elec-

trode clean. It should always be applied moistened with warm water or a warm saline solution. It should be applied firmly to the site of contact and kept moist.

Some operators prefer to apply the indifferent electrode nearer the site of the application of the *active electrode.* In application of the current to parts of the oral cavity, when it is desired to place the indifferent electrode near to the site of contact of the other electrode, one such as is shown in the illustration (Fig. 43), invented by Dr. Lewis Jones, should be placed under the chin and held in firm contact with that surface. This electrode possesses the advan-

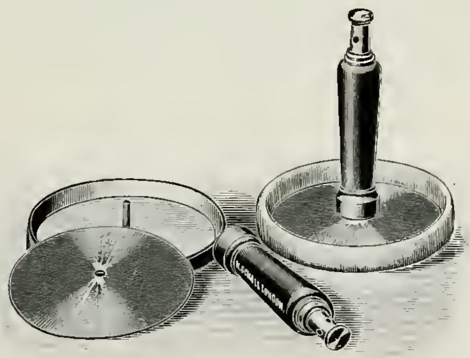


Fig. 43.—Indifferent electrode.

tage of being readily covered with a new clean cover for each patient. It is made in sections which allow of a new cover being easily slipped on. Electrodes of this description are a little awkward to manage at first but are very good for application to this part of the body.

If the electrode is not large enough or if it does not make good contact the current is liable to cause blisters to the skin at the site of contact of the indifferent electrode, even when a small current is passed. In the case of the hand electrode, if the metal is of small size and not grasped firmly by the patient, a small, hard, white blister about the size

of the head of a large pin may appear at some point in the palm of the hand, attended with some discomfort to the patient, the skin dies at this point and the mark will only disappear when the skin is removed a long time after. To obviate this occurrence place a carbon electrode, covered with a couple of folds of flannel into a glass vessel filled with slightly warm water and some sodium chloride, the

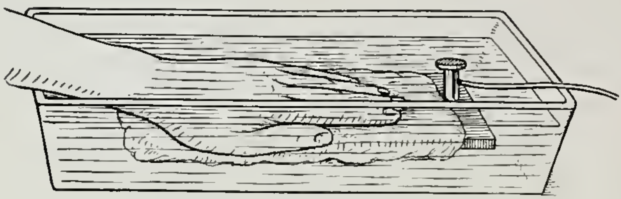


FIG. 44.—Carbon and water electrode.

patient's hand must be immersed in the water and the palm of the hand pressed firmly on the covered carbon conductor at the bottom of the glass dish. This is always a comfortable form of indifferent electrode, which patients appreciate, especially if pain is experienced by contact of other forms of metal electrodes. The connecting cord from a water electrode should be rubber insulated copper wire.

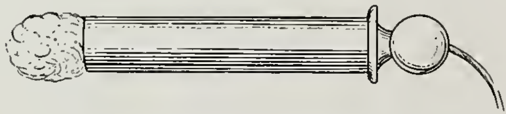


FIG. 45.—Hand electrode.

Another form of indifferent electrode quite well adapted for ionic medication consists of a *nickel-plated* metal handle which the patient holds. This should have a moistened sponge at the open end and should be covered with stockinette or lint moistened with salt and water. It should not be of brass or copper as sometimes made, and should be of

the largest size displayed by makers. This form of electrode is preferred by some patients, as they seem to like to hold on to something; the epidermis of the palm of the hand is thick and not usually sensitive to current of small ampèrage such as is usually required for applications to periodontal membrane.

The chin electrode devised by the author consists of a nickel-plated metallic plate which fits under the chin with a contact screw soldered to the middle and end pieces to

FIG. 46.—The author's chin electrode.

receive an adjustable elastic strap which is intended to pass over the head and hold the electrode firmly in place. It should be covered with a pad of lint next to the skin, and should be moistened with salt water. This form of electrode for contact on the face is comfortable and useful where it is desired to lessen the resistance by having the electrodes in close proximity.

Active electrodes convey the current to the site of application. They consist of an insulated rubber or ebony handle with an attachment screw at one end to connect

the conducting cord to, the other end should consist of an interchanging screw piece to receive the particular applicator required; the electrodes to fit these handles should be of platinum, zinc, or copper, and shaped according to

Fig. 47.—The author's electrode hand piece.

the requirement of the operation; for pyorrhea pockets or gingival trough, spear-shaped metallic points of the metals mentioned, 5 cm. long by 2 mm. wide and 1 mm. cross-section. These should be interchangeable at the hand piece and readily removed for sterilizing. The extreme ends

Fig. 48.—The author's pyorrhea electrodes.

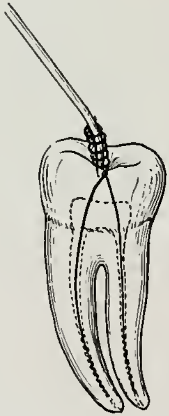


Fig. 49.—The author's root canal electrodes.

should be rounded, as sharp points increase the density of the current which makes it painful. The points are flexible (except zinc), which permits of them being bent to suitable curves for different angles when required to pass to the

approximal surfaces of molars. The shanks of the points should be insulated three-quarters of the length to prevent the current passing to the lips and cheeks adjoining the site of application. (See Fig. 48.)

For root canals, electrodes of fine copper or platinum wire twisted into a coil at one end and straightened out for varying lengths of half to one inch in length, the straight part for insertion into the root canal, and the coil to receive the end of a spear-shaped point attached to the ordinary handle, to hold it steadily in position when being used (Fig. 49). Iridio-platinum wire electrodes are best for treating root canals.

Copper probes for fistulous tracts of chronic alveolar abscesses should be made with this coil at the one end to receive an ordinary electrode with which to make contact when applying copper ions, as will be described later. The thickness of these probes should be 0.5 mm.

Rheostat for Direct Current from the Main.—The continuous current from the main is the most convenient source of supply of electricity for ionic medication. It is quite safe, notwithstanding the high E. M. F., if only ordinary precautions are adhered to, and it is not any more painful to use than the current furnished by a battery.

The current from the main must be reduced to very low voltage with a minimum output of current strength. This is accomplished by suitable resistance interposed on the *switchboard* between the supply and the patient. The current is controlled by passing it through a coil of resistance wire which is wound around a core of insulator material, like slate. Each turn of wire is insulated perfectly from the next, although placed very close to it. Several hundred turns of the wire represents a resistance sufficient to reduce the current of 240 volts to 0.15 volt. A lamp is also placed in circuit which when the current is switched on, assists in reducing the current and acts as a guide to indicate the presence of the current and a safeguard against sudden rise of current by accident to the insulation of the wire resistance.

The principle of the switchboard resistance is explained in the diagram; the current passes from *A* to *B* through the resistance coil. At *B* a contact sliding metallic spring (*C*) is adjusted on a metal bar over the coil; this moves in the direction *A* over the resistance; the sliding contact is connected with the + terminal of the switchboard; the end of the coil at *B* is connected with the − terminal; an incandescent lamp is also on the negative side of the board. It can be readily seen by the diagram (Fig. 50) that the current must pass through the entire resistance before it reaches the contact spring *C* when it is adjusted at *B*, and that

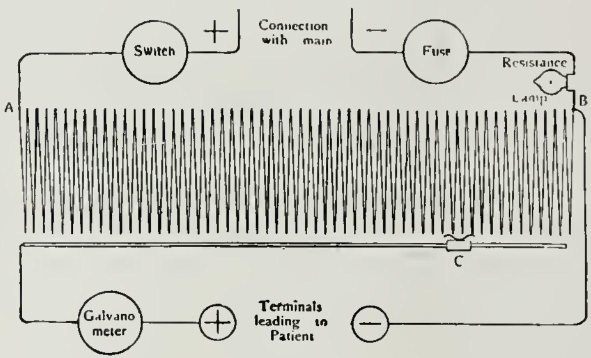


Fig. 50.—Plan of switchboard resistance.

by sliding the spring toward *A* the resistance is gradually reduced and the current strength increased. The E. M. F. when the current passes through the entire resistance is only a fraction of a volt; as the spring slides over the coil from *B* toward *A* it increases the E. M. F. very gradually by about 0.1 volt as it passes over each turn of the wire coil. A milliampèremeter, which should always be used, is placed in circuit between the resistance and the + terminal by a connection to the metal bar upon which the contact spring *C* slides. Current controlled from the main by this method seldom gives any trouble, as the operating chair is usually perfectly insulated, but it must be borne in mind

that in these wire circuits if the negative pole is brought in contact with anything connected with earth, when the circuit is closed, a severe shock is liable to occur from this source, even if the current at the positive pole is reduced to minimum by the resistance. For this reason it is dangerous to use a metallic saliva ejector when using the

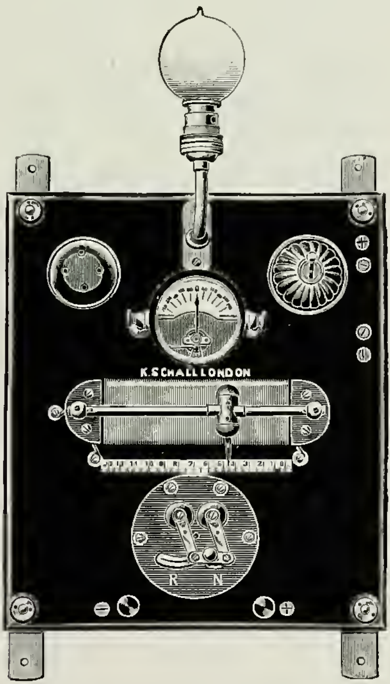


Fig. 51.—Switchboard for ionic medication.

current in the mouth, for the water might make perfect contact with the earth through the metallic pipe connections. No water pipe or gas fitting should be touched by the operator or patient when the current is being used. It is possible for very damp weather to so moisten the carpet on which an operating chair rests that imperfect

contact is made with earth and thus to become a source of contact when using the current. This can be overcome by insulating the chair perfectly by placing the base on a rubber mat.

Current controlled by this form of rheostat switchboard (see Fig. 51) is used for all kinds of galvanization and ionic medication; the E. M. F. is reduced and the current strength brought down to a minimum, and differs from the switchboard used for cautery or hot-air syringe, which requires a current of high ampèrage with a low voltage, and which cannot be used for ionic medication.

Resistance for Heavy Currents.—The current which is required from a switchboard for cautery light, hot-air syringe, water heater, etc., of the type now much used cannot be controlled by wire rheostat resistance inserted in circuit on the principle of the galvanic switchboard. The resistance in series which will permit of strong enough current strength to heat a cautery loop would require an electro-motive force which would be sufficient to establish an electric arc at the moment of breaking the current in the handle of the cautery which would destroy the instrument, or should the platinum loop be overheated and become fused when in use, the danger would be serious. The principle of resistance for these switchboards is one which is known as the *shunt circuit;* it consists of two parallel circuits: one for the current, which is required for the instruments, the other acting as a shunt circuit in case of overheating or fusing of any other connection on the switchboard; there are a number of resistance coils of thick wire attached to the back of the switchboard which are connected in series with conducting studs at intervals, which lead the current to the front of the board, where several crank arms are attached to switch on the required current for the different instruments for which the particular current strength is intended. There is a pilot lamp at the top of the board which indicates the presence of the current. The current strength of the different instruments is regulated by the length, thickness, and number of coils in the wire which

form the rheostats at the back of the board, different ampèrage being necessary for different individual instruments or sets of instruments.

When the current is switched on, a large amount of current is constantly passing through the shunt circuit which of course is not used, in this there is considerable waste, and the current should not be left on the switchboard except it is in use.

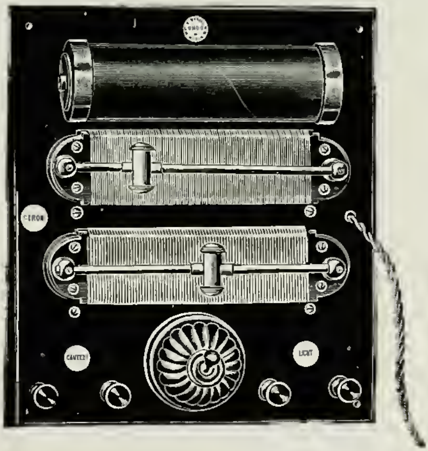


Fig. 52.—Transformer for light and cautery.

Alternating Current Transformers.—It is desirable sometimes to change the alternating current from the main into continuance current, or to transform it into one of low voltage and high ampèrage for cautery or lamp; this is accomplished by *induction*, or *motor transformers* or by *rectifiers*.

By an induction coil on the principle already mentioned, the current of high voltage can be transformed into one of low E. M. F. and high current strength, or by having two coils wound on a ring of soft iron, a primary with a greater number of turns in the coil than the secondary, the current passes through the primary and induces current

in the secondary which is in the magnetic field of the coil. Current transformed in this manner is used for cautery and light. For producing the opposite effect, that is, transforming the current into much higher E. M. F., the winding of the coils is reversed, the primary with a fewer number to turns in the coil than the secondary. Current transformed in this manner can be used for high-frequency apparatus, or if a synchronous commutator in the secondary circuit is employed, for the *x*-ray work. The switchboards are provided with sliding resistance for adjusting the voltage to the required strength. These forms of transformers are much used for cautery and light. They are sometimes arranged to give two or three different voltages, by having two or three secondary windings wound on different parts of the iron ring, each having different numbers of turns of wire, and induce different currents that are taken to different terminals on the switchboard. One coil of thick wire and of few turns gives a current of low voltage and high ampèrage for cautery; another of finer wire and more turns gives a higher voltage and a certain ampèrage for lighting small lamps; a third of still finer wire and more turns gives a current for therapeutic work. Current transformed on this principle is readily regulated and answers the purposes for which it is intended.

To transform an alternating current from the main into a continuous, a *motor* which works by the alternating current is required. This is made to transmit mechanical energy to work a direct current dynamo from which the direct current is collected. By a motor transformer a continuous current can be obtained of almost any desired electro-motive force and current strength suited to windings of continuous current engines and lathes or galvanic switchboards, and other dental devices for which a continuous current is required. For medical purposes this form of transformer is useful for spark coils, arc lamps, or electro-magnets, and it may be used for charging accumulators.

High-frequency Currents.—High-frequency currents may be described briefly as alternating electric currents which

discharge with oscillations of great frequency. The oscillations may amount to millions a second and vary in continuity and frequency with conditions of capacity, induction, and resistance, in production of the discharge. It is beyond the scope of this work to describe in detail phenomena of high-frequency discharges. The present efficiency of apparatuses for production of high-frequency currents is due to the studies and ingenuity of such authors as Sir

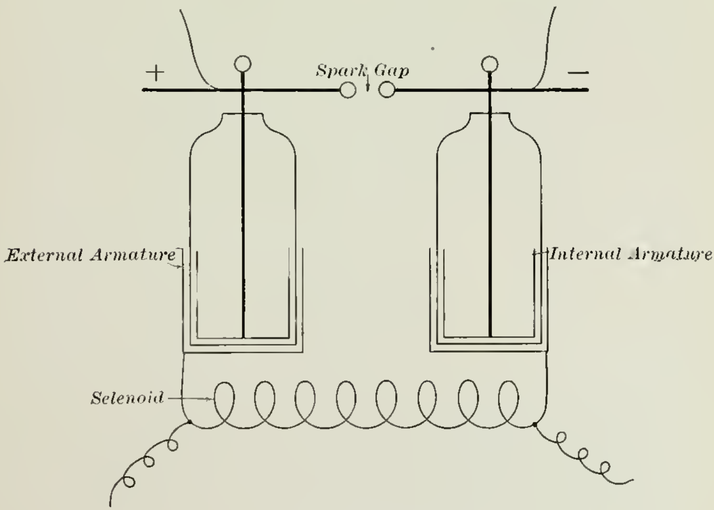


Fig. 53.—d'Arsonval's principle of high-frequency apparatus.

Oliver Lodge, Hertz, Tesla, Elihu Thomson, and d'Arsonval. d'Arsonval discovered the present-day principle of the high-tension high-frequency coil; he connected the internal armatures of two Leyden jars with the terminals of a secondary current from an induction coil; to the external armatures he connected a spiral of about twenty turns of thick copper wire. To the internal armatures he connected on an upright two horizontal metallic rods which terminated in rounded ends to form a spark gap. He discovered that

on charging the condensers, each time a discharge spark crossed the spark gap a high potential current with oscillations of a high frequency was set up in the spiral attached to the external armatures and that this form of current could be collected from the ends of the coil (see Fig. 53). Many of the modern instruments for producing high frequency are constructed on the principle of d'Arsonval's discovery. The electrical source of energy to work a high-frequency apparatus is best obtained from continuous or alternating main current supply, but primary and secondary batteries can be used. In using current from the main the ratio of electro-motive force and current strength must be altered, this is accomplished by induction coil current interrupters, motor converters, etc., constructed on the principles already described. The apparatus consists of condensers, spark gap, solenoid, and resonator.

Condensers consist of two Leyden jars or glass plate condensers constructed on the principle of Leyden jars. They are connected by contact with their inner coating of tinfoil or metal conductor, with a secondary coil, or high-tension transformer or whatever the source of electrical energy may be. The *spark gap* is formed by two adjustable conductors which are in contact with the conductors attached to the internal lining of the condensers, the spark gap is usually enclosed in some form of covering which deadens the sound of the spark, when the discharges between the two jars take place. The *solenoid* is a coil of copper wire which is connected to the outer covering of the condensers. It usually consists of about twenty turns of thick copper wire. The *resonator* is made in several forms, and consists in one form (d'Arsonval's) of four turns of thick wire which is connected at each end to the outer coating of the condensers; on the outside of this coil, placed about two inches away from it, is a secondary coil of fine wire made of a great number of turns over an ebonite cylinder. This secondary coil induces currents of higher tension than the outer coil of thick wire.

The several parts of the apparatus are assembled and

mounted on a small table, or as is the case of a small portable apparatus, in a strong wooden box. The usual type of apparatus for medical purposes is shown in the accompanying Fig. 55. The condensers are placed on the lower platform of the table and are connected by the inner coatings

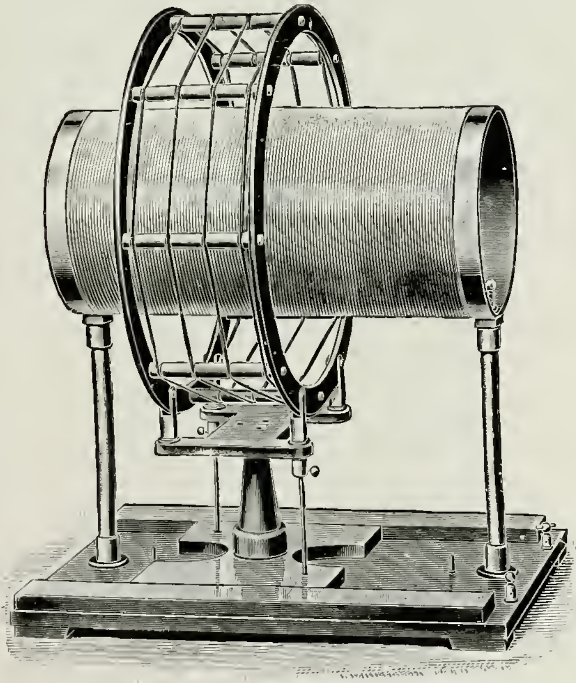


Fig. 54.—High-frequency transformer.

to the secondary terminals of an induction coil worked by motor interrupter and also to the spark gap which is enclosed in a box inside which the sparking takes place between the metallic knobs which are adjustable to suit the spark desired.

The outer coatings of the condensers are connected through the solenoid, from which the currents are conveyed

to the patient. The resonator is made of a coil of copper wire, which is wound around a frame and placed on the

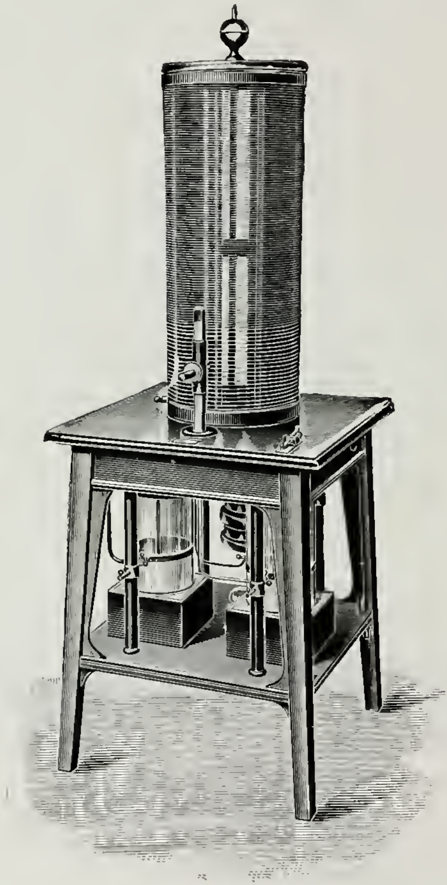


FIG. 55.—Combined high-frequency apparatus.

top of the table. These two are connected in different ways according to the make of the apparatus; some have adjustable contacts.

A milliampère meter of the hot wire type (Fig. 56) is usually connected between the patients and the solenoid, or the resonator of the high-frequency apparatus.

High-frequency currents conducted from the solenoid to the body are of great magnitude. d'Arsonval has shown by experiment that an incandescent lamp placed in series between the instrument and the patient, so that the current must flow through the lamp before reaching the patient, will glow brightly, yet no unpleasant sensation is noticed if the electrodes are firmly grasped. It would be impossible to pass a similar current without serious effect on the body.

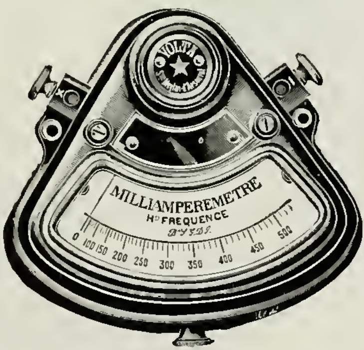


Fig. 56.—Hot wire milliampère meter.

In general electrification of the body by high-frequency currents different methods are adopted for passing the current to the body; by direct conduction from the ends of the solenoid; by conduction from one end of the solenoid with the other end connected to a conductor placed in proximity but not touching the patient; and by auto-conduction, which consists in placing the patient in spiral wire enclosures large enough to completely enclose him without touching him, the current passing through the wire enclosure or solenoid is transmitted by induction.

In the use of high-frequency currents for local application in dental treatment a modified apparatus is required. This has been carried out in one form by what is known

as the Tesla transformer principle, which requires no motor interruptor. The apparatus is connected to the main, continuous or alternating current, by a wall plug, the current passes through an arrangement of induction coils and a spark gap which regulates the potential and frequency. The current is conveyed to the mouth of the patient by a vacuum glass electrode which when in poor contact with the tissues produces slight heat, and if held a slight distance away produces a small brush spark. The sparking gap is only

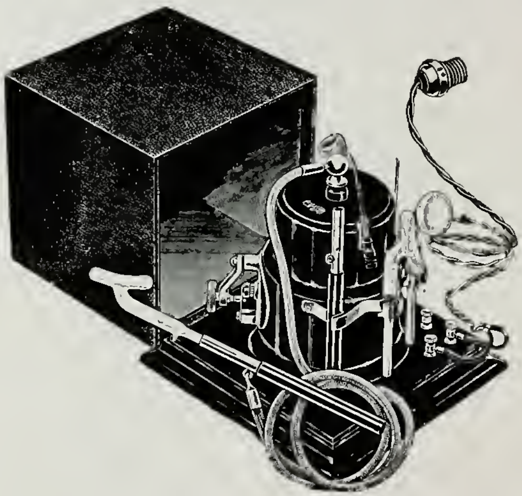


FIG. 57.—Victor Gem high-frequency apparatus.

two or three inches wide, which produces high-frequency currents of sufficient ampèrage for treatment of oral tissue.

Such an apparatus is shown in the cut. It is of American make, called the Victor Gem high-frequency coil, Messrs. Ash & Sons being the English agents. Glass vacuum electrodes made to shapes adaptable to treatment of the gums, supplied with this outfit, are admirably suited for the purpose; a wire conductor passes through the glass, conveys the current and establishes connection between the interior of the electrode and the conductor.

CHAPTER VI.

DENTAL ELECTRICAL APPLIANCES.

Motors — Electric Engines — Electric Lathes — Switchboards—Accumulators—Direct Resistance—Motor Converter—Electric Hot-air Syringe—Electric Sterilizer and Hot-water Apparatus — Foot Warmer — Electric Furnaces—Pyrometer—Electric Gold Annealer.

Motors.—Motors for operating room engines, laboratory polishing and grinding lathes, ventilating fans and compressed-air pumps, are usually constructed of a pair of fixed electro-magnets for generating a magnetic field, an armature which revolves in the magnetic field, and a controlling resistance for regulating the speed.

The electric field magnets consist of two separate coils of insulated wire wound in opposite directions and fitted on shaped soft-iron cores or pole pieces. The armature is the driving force of the motor and consists of a number of coils of wire wound in slotted plates fitted to the spindle. The ends of the coils terminate at a commutator, which is composed of a number of copper segments insulated from each other and from the steel spindle to which it is fixed. On the surface of the commutator a pair of brushes make contact and are held in position by suitable holders and springs, which hold the brushes firmly against the surface of the commutator as the armature revolves. These brushes carry the current supply to the armature.

The surface of the commutator should be kept smooth and clean and sufficient tension given to the brush springs to keep the brushes from jumping as the armature revolves, not enough, however, to cause undue wear between the surfaces of the brushes and the commutator. To clean the commutator a piece of soft cloth should be firmly wrapped around

the tip of the forefinger, moistened with spirit and pressed onto the surface of the revolving armature. This can be done with ordinary care, without fear of shock. The motor should then be stopped, the brushes should be lifted and the contact surfaces carefully wiped. Should the brushes be of metal gauze, care should be taken not to fray the edges, as frayed edges cause sparking at the brushes, which must be prevented, because it burns the surface of the commutator and makes it uneven, and may later on lead to a burn-out of the armature. If the surface of the commutator is at all rough, or blackened carbon brushes are used, a piece of fine sand or cuttle fish paper should be held flat on it as the armature revolves, until a smooth, bright surface is obtained. Any dust on the brushes and commutator should be afterward carefully wiped off. *Emery paper should not be used.*

Motors which have carbon brushes should have the surfaces of all internal parts wiped clean from carbon dust, since if this is allowed to deposit it may in time cause a short circuit and seriously damage the motor.

The bearings should be sparingly oiled and every care should be exercised not to allow surplus oil to run over the insulating material of any wires, as oil destroys it by its action on the rubber.

Careful attention to the above-mentioned points will insure long life to the motor and often save an expensive "burn-out."

Electric Engines.—There are a number of electric engines on the market, chiefly of American and English manufacture, the original being the well-known "Columbia," made by the Ritter Dental Manufacturing Co., of Rochester, U. S. A. The motor is enclosed in two metal hemispheres and hangs by a circular cord from a suitable wall bracket with pulleys, and is about $\frac{1}{30}$ horse power. The suspension cord consists of four feed wires, two for the field magnets and two for the armature. These are twisted together and covered with insulating cotton and silk, built into a neat circular form. The cord passes over the two pulleys and down the wall on which the bracket is fixed, and has attached to it a lead weight

to counter-balance the motor and to admit of it being raised or lowered with a light touch of the operator's hand. The cord finishes at a small contact plate or resistance box which is fixed to the wall, usually from one to two feet from the floor, and fitted with a pair of terminals for connecting the engine to the electric supply mains, by means of ordinary twin flexible wire; it also acts as a connecting plate for the ends of the floor cable which leads from the foot controller. This cable contains four to eight separate wires.

The resistance usually consists of a number of coils of wire, wound on some suitable insulating material and enclosed in a separate box or in the foot controller. These coils have wires which lead to copper contacts in the controller, over which pass spring contacts, worked by means of a foot lever. The contacts control the entire working of the motor—starting, stopping, speed regulation, etc.

The controlling lever of the foot switch generally has a free swinging movement and requires to be held in position with the operator's foot while the motor is in action. Some manufacturers fit a locking device which holds the lever in any desired position and is released by a slight tap with the foot. The locking device is not so safe as the free lever, as a few seconds may elapse in releasing the lever, whereas with the free swinging lever the withdrawal of the foot instantaneously stops the motor.

Foot controllers should be opened occasionally and carefully cleaned, especially the surfaces of the various contacts. After cleaning, the surfaces should be smeared with a very slight film of oil, to prevent wear of the two copper surfaces by friction. Too much grease will cause loss of power in the motor, on account of its insulating properties.

Other designs of engines found in catalogues of the dental manufacturers and supply houses are all practically constructed as described above with various modifications, chiefly in the controller; some are fitted with the flexible cable, and others with the all-cord arm for receiving the hand-piece and instruments.

The all-cord arm is superseding the flexible cable arm to

a very large extent, although the cable arm possesses the advantage of adaptability, particularly in the wrist, and this, from the operator's point of view, is a great convenience.

Electric Lathes.—These are more simple than engines for operating rooms, and usually consist of a motor, which varies from $\frac{1}{20}$ to $\frac{1}{4}$ horse power with suitable spindles. The motor case is completely closed, ventilation holes not being necessary, as these lathes are not, as a rule, run for long periods, and do not generate much heat in the coils; it is also important that grit and moisture from the polishing brushes and grinding wheels be excluded from the working parts. The armature spindle extends on each side of the motor beyond the bearings for about an inch, and on these ends the chucks are fixed; they are very slightly tapered while the chucks are correspondingly tapered. Chucks fitted in this manner are held very securely on the spindle, and can only be removed by direct pressure along the spindle, such pressure being usually applied to the outside of the bearings.

Switchboards.—Various forms of switchboards have been specially designed and manufactured for dentists' use. These provide methods for supplying and controlling both high and low voltages by means of suitable switches, safety "cut-outs," regulating rheostats, etc.

These switchboards are usually made up in panel form arranged for attachment to the wall or cabinet, within easy reach of the operator. The panel is generally either of marble or enamelled slate fitted to a metal frame, and contains the necessary connections, wire resistances, etc.

The high-voltage circuit, as a rule, has four or six terminals to which flexible wires can be attached for the engine, lathe, fan, gold annealer, reflector, sterilizer, hot-water apparatus, etc., or to any appliance which is made to work with the same electro-motive force as is possessed by the particular current supply available. Each terminal is controlled by a quick break switch, and a "cut-out," and the operator can switch the current on to or off from any of these appliances, without moving from the chair side. It is important that the fuse wires in cut-outs should be of

the correct size to carry the ampères required by each apparatus; heavy fuses for low ampèrage appliances are practically useless. Fuses are intended for the purpose of protecting the appliances in use and preventing them being burned out or injured by a sudden increase of current, due to some defect or short circuit.

The approximate sizes of fuse wires required for high voltages (200 to 250 volts) are as follows:

For motor, engine, lathe, fan, reflector, etc., 1 ampère.

For Mitchell's low-fusing inlay furnace, annealer, atomizer and tumbler heater, 2 ampères.

For high-fusing inlay furnace, sterilizer, and hot-water apparatus, 3 to 5 ampères.

Low-voltage circuit is required for such appliances as cannot be used from the full voltage of the current supply, as, for example, mouth examining and antrum lamps, root-drier, cautery, gutta-percha heating instruments, hot-air syringe, etc. These usually require a current of from 2 to 12 volts, and from ½ ampère to 8 ampères.

When the current is alternating, the low-voltage circuit is easily attainable from a suitable design of transformer, fitted either on the front or back of the switchboard panel. This circuit consists of primary and secondary coils wound on a soft-iron core of convenient shape, and a regulating rheostat for graduating the voltage and ampèrage in regular and gradually increasing ratio. The low-voltage current used is taken from the secondary coil which is quite separate from the main current supply.

When the current is continuous, especially if it be of high E. M. F. (200 to 250 volts), the difficulty in reducing the E. M. F. to 2, 4, 6 volts, etc., and at the same time obtaining a graduated ampèrage at these low voltages, is very much greater, and represents a heavier loss of current than when the current is alternating. There are various methods employed for this purpose. The three most practical ones are those used by the various manufacturers, viz., accumulators, direct resistance, and the motor converter.

Accumulators.—A two-cell accumulator which gives a little over 4 volts when fully charged, is connected to a pair of terminals on the lower part of the switchboard. By means of wires behind the board the cells are connected to a resistance coil with a sliding contact, which is connected to three or four terminals on the edge of the board. The flexible wires for the mouth lamp, cautery syringe, etc., are connected to these terminals. All these instruments are constructed to work on from 2 or 4 volts. The current from the cells passes through the resistance and by slowly moving the sliding contact from one end of the resistance toward the other, the current can be very gradually increased until the correct strength is obtained to light the lamp or heat the instrument required for use.

The cells are usually charged through high candle-power lamps fitted on the upper part of the board, which act as resistance to the high voltage of the current supply. The lamps should be of the same voltage as the lighting or power current used. The lamps are switched into the accumulator circuit by means of a double pole-switch, so that when the current is being taken from the cells the high voltage supply can be disconnected; this prevents the possibility of either operator or patient receiving a shock, which might happen if a single pole switch is used.

A voltmeter is attached for detecting the lowering of the power in the cells; it is most important to keep these fully charged, if the E. M. F is allowed to drop below 2 volts, the acid in the cells acts on the plates and quickly destroys them.

The method of reducing the direct current by accumulators works satisfactorily with a little care in keeping the cells always charged to their full capacity. The resistance lamps produce considerable glare during recharging and are in that way objectionable.

Direct Resistance.—In this form of resistance the back of the switchboard is fitted with coils of resistance wire, or other resistance material in the form of metal plates, the wire being of the correct gauge and length to reduce the

high-voltage supply to 2 volts and a fraction of an ampère. For voltages of from 200 to 250 volts, coils of thick iron wire of considerable length, with ample air space, are attached to the back of the slate slab. The current in passing through the wire resistance generates considerable heat which is dissipated in the ventilation spaces provided.

At regular distances along the main resistance, short wires are attached and connected to a series of studs on the switchboard—some thirty or more in number. A sliding contact passes over these studs and reduces a portion of the resistance at each step, thereby gradually increasing the strength of the current to the terminals which are connected to the circuit for the use of the cautery, syringe, root-drier, etc. As the resistance is reduced the ampèrage rises in proportion, and also the temperature of the wire. They are at their maximum when the cautery is in use; this instrument generally requires a current of from 6 to 8 ampères and E. M. F. of 2 to 4 volts.

Where a cautery is used from currents of 200 volts upward, it is often considered advisable to fit the heavier resistance wire into a separate frame, suitable for standing on the floor, in order to reduce the heat given off at the back of the board.

This arrangement is not dangerous or as wasteful as may be imagined, for these low-voltage appliances are, as a rule, only required occasionally during an average day's practice, and then only for very short intervals, probably only for two or three minutes at a time, it will readily be seen that the current is not passing through the resistance long enough to produce much heat or to waste any great quantity of current. With ordinary care no trouble may be anticipated, but it is advisable to have a lamp fitted on the board to act as a signal. This lamp only lights when the resistance circuit is in use; the light will then always warn the operator that the current is still passing, should he forget to switch off the resistance after using the cautery, syringe, etc.

With the direct resistance method one pole of the main supply is always connected to the low-voltage terminals, hence it is possible to receive a shock if the handles of the

appliances used are not perfectly insulated. The advantage of the method is that so long as the main current is available the supply is always certain, and the operator is saved the necessity of constantly watching the apparatus, as is necessary when accumulators (which require regular charging) are used.

The Motor Converter.—An alternating current is the most satisfactory for producing low voltages; when a fairly heavy ampèrage is required it is readily transformed with very little current loss or heat and with absolutely no risks of shock from the high-voltage circuit.

When a continuous current has to be used, the safest and best method of producing the low-voltage current is by means of a motor converter. This consists of an ordinary continuous current motor with alternating current collecting rings and brushes fitted to the armature at the end opposite to the commutator. This combination when run by the continuous current acts both as a motor and a dynamo, an alternating current is given off from the collecting rings of the armature, which is conducted by a pair of wires to a primary coil of a small transformer fitted to the switchboard. This produces a low-voltage current which passes through the secondary coil of the transformer, from which it is conveyed by means of a sliding contact. A graduated current is by this means obtained to suit voltage and ampèrage of the various instruments.

The only disadvantage of the motor converter method is that a small motor is necessary, in addition to the switchboard, but all trouble of attending to accumulators, the need of heavy resistance coils, and the unavoidable heating are done away with; moreover, all risk of shocks to either patient or operator is entirely avoided.

If desired, the motor can be put out of the way in a box or cupboard, or it may be placed in another room and controlled by a switch on the switchboard. In addition to the special work for which it is intended it can also be used in the operating room as a lathe, *when not employed for generating the low-voltage current.*

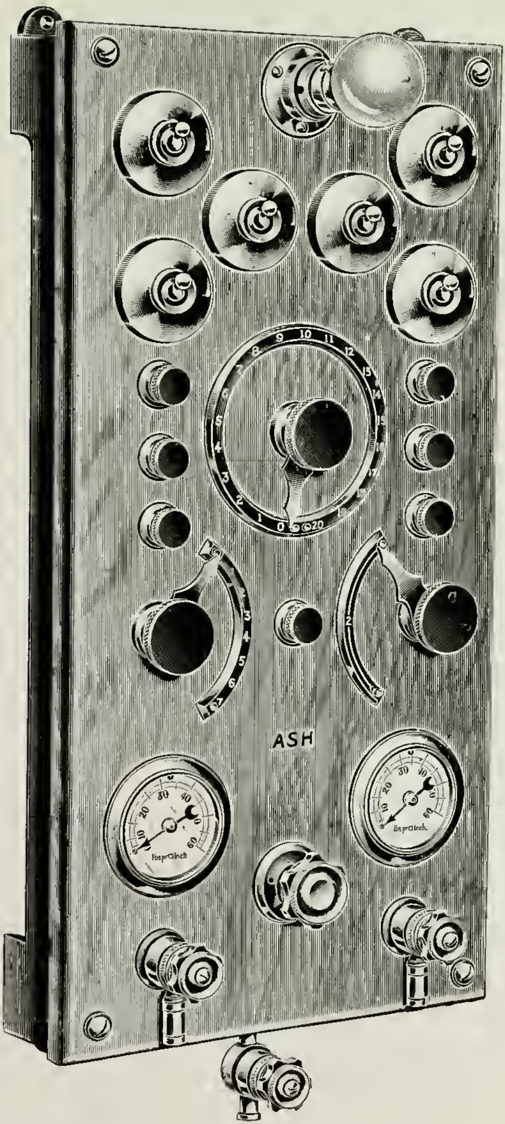


Fig. 58.—Switchboard.

By this method the low-voltage circuit only is converted to alternating current; the high-voltage continuous current circuit remains unaffected and always available for motor power.

A modern switchboard is shown in Fig. 58. This is supplied either with the direct resistance or with the motor converter. When the motor converter is employed the motor is fitted for use as an operating-room lathe and thus answers a double purpose.

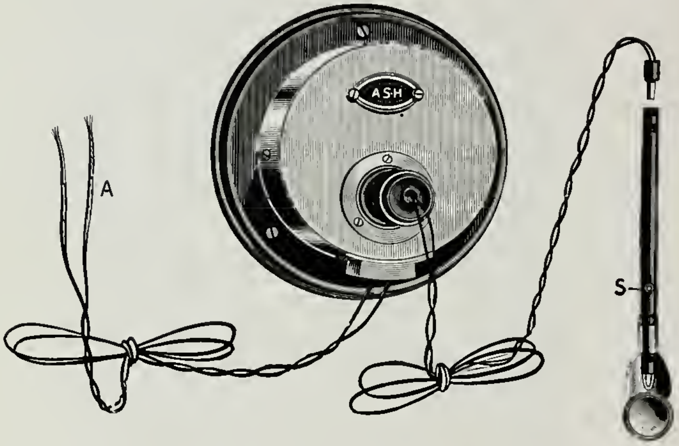


FIG. 59.—Mouth lamp from main.

Electric Hot-air Syringe.—This usually consists of a platinum coil fitted inside a glass tube, protected by a metal sheath which is perforated, to admit of the coil being seen, so that the current can be adjusted to produce the proper degree of heat. The syringe is adapted for use with compressed air. The electric current and air supply are switched on or off by a single movement of the switch which is fitted in the handle. The current required for working it is 6 volts and from 4 to 6 ampères.

A syringe is made which can be worked without any resistance direct from any current of high electro-motive

force. A separate switch with a valve controls the current and air supply. The current, which is only in circuit for about half a minute at a time, generates sufficient heat in the coil for three or four minutes' use.

Electric Sterilizer and Hot-water Apparatus.—A form of sterilizer consists of a water container made of brass which is pressed from one piece, it has therefore no seams or soldered joints. The heating element is composed of a special alloy made into a flat wire which is wound on an iron plate insulated with mica. Two of these elements are fitted in the bottom of the water container to which they are firmly clamped and connected with wires to three terminals which are fixed to the base. Connectors provided with triple flexible wires admit of four different temperatures.

The sterilizer is so designed that, in case of an accidental fusing of the heating elements, the base can be removed, the elements taken out and repaired or replaced by new ones.

Care should be exercised with sterilizers or any form of electrical hot-water heaters, not to allow the containers to become dry when they become overheated and destroy the heating elements.

A form of sterilizer, of American manufacture, known as the "Monarch" Visible Sterilizer, is made of cast aluminium which is strong, light, and easily cleaned, the glass vessel is made of specially annealed triple lead glass which the manufacturers claim will not crack with ordinary use. The heater is in the form of an immersion element made of cast brass, in which a special form of wire is fitted, wound, and insulated in such a way that it will stand constant use without risk of fusing, provided the current is not switched on except when the element is in the water. When not used for sterilizing purposes the glass vessel can be employed as a heater for the atomizer bottles.

Many forms of electrical jugs, kettles, and tanks are made for heating and boiling water in the operating room, which are constructed on the principle described.

Foot Warmer.—The foot warmer consists of a thin metal case which encloses a wire resistance designed not to reach a

high temperature, even though the current be left on for a considerable time. It is covered with carpet which gives it a neat appearance, and the heat generated is just comfortable to the feet.

Electric Furnaces. — The electric furnace is made of a fire-clay muffle wound with platinum or iridio-platinum wire which is capable of withstanding very high temperature and produces heat for fusing metals or porcelain bodies.

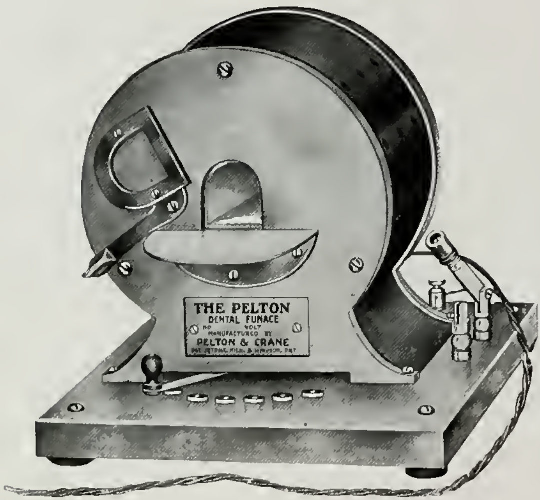


Fig. 60.—Pelton electric furnace.

Platinum, although capable of resisting great heat, will occasionally become overheated and the fusing of the coil destroy the furnace; the principal cause of this is switching on current too suddenly. The wire is wound in grooves on the outer surface of the muffle which provide perfect insulation when expansion takes place during heating; a short circuit would cause fusing of the wire.

The wire used in wiring a muffle varies in diameter and length according to the voltage of the current to be used and

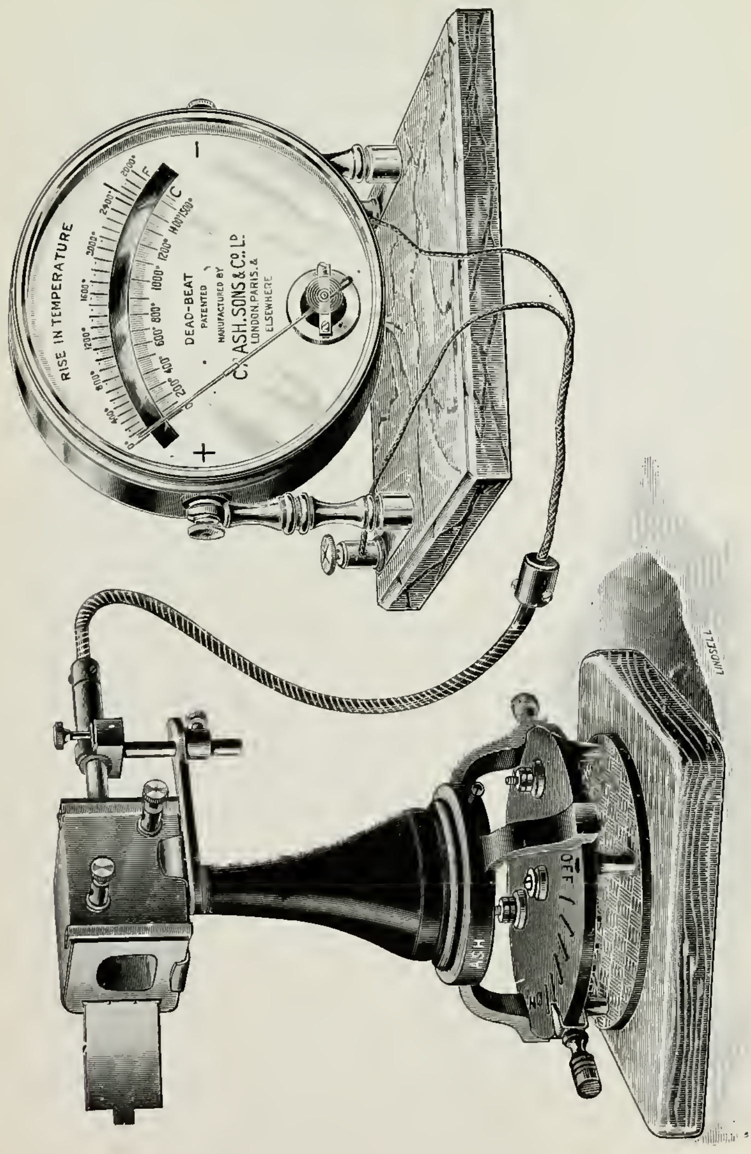


FIG. 61.—Pyrometer.

the temperature required. Very accurate calculations are necessary to determine these points and to ensure correct resistance in heating the wire to the right temperature without overheating, or, on the other hand, not heat the furnace sufficiently.

Pyrometer.—The pyrometer is used for registering the temperature generated in a furnace. It is connected by a thermo-couple to the muffle. The fusing-point of the metal or porcelain body being known, the required heat is registered on the dial of the pyrometer and fusing accomplished without opening the furnace.

The pyrometer is a very delicate instrument and somewhat expensive. It works independently of the ordinary electric current supply and develops a thermal-electric current in its own circuit. The thermo-couple consists of two pieces of wire, platinum, and iridium, which are insulated from each other, except at their extreme ends. Two of the ends are fused together while the other two have flexible wires attached for connecting them to the terminals of the pyrometer. The fused part is fitted into the furnace muffle and the action of the heat generates the thermal current which passes along the flexible wires and acts on a small coil in the pyrometer which deflects the needle.

Electric Gold Annealer.—The electric annealer is made of a fire-clay slab three inches square, divided into sections, wound underneath with platinum wire, and fitted to a small stand with a metal cover. Pelton's annealer is fitted with a regulating resistance which regulates the temperature.

CHAPTER VII.

THE X-RAYS OR RÖNTGEN RAYS.[1]

X-ray Apparatus—Dental Radiography—The Uses of the X-rays in Dentistry—Development of Radiographs.

The Röntgen Ray Apparatus.[1]—X-rays are produced by passing an electric spark, usually from 10 to 18 inches long in air, from an induction coil or other electric machine, through a special glass tube having a high vacuum, and enclosing terminals known as the cathode and the anticathode, which latter is frequently joined to another called the anode.

Cathode rays are thus produced in the tube, which striking a target (anticathode) made of metal of high atomic weight and fusing-point, give off the *x*-rays in the tube, which penetrate the glass sides of the tube on the same side as that of the anticathode struck by the cathode stream.

X-rays thus produced in the air have the power of penetrating all substances more or less, according to their strength and also in the same ratio as the atomic weight or density of those substances. They also have the power to fluoresce certain substances, as barium platino-cyanide, potassium platino-cyanide, tungstate of calcium, etc. The *x*-rays also affect photographic plates of all kinds more or less, according to the thickness and quality of the emulsion, the effect being produced in all probability by bombardment of the *x*-ray particles.

Special *x*-ray plates are made and at the present time the Ilford are the best. Of the photographic varieties, the "ordinary" speed are usually better than the "rapid," but again the writer has obtained excellent results from such

[1] By Mr. Charles A. Clark, of London.

fast emulsions as Paget 5X Lumière's Sigma, and Extra Rapid, though all of these require a longer exposure than the special x-ray plates mentioned.

At the present time for obtaining the current for the x-rays the coil is the most usual instrument. At first these were made to give a spark of a certain length only, but now the great aim is to obtain not only length of spark but as large a current as possible. Different makers have different methods of building coils, and a general description only will therefore be given.

The coil consists essentially of (1) an iron core; (2) primary winding, and (3) secondary; between these two latter there is a thick ebonite tube. In the early days the iron core was made rather too small; it is now made of bundles of thin, soft-iron wire or of soft-iron laminæ.

Outside this core is the primary (duly insulated from the core) of thick, double, cotton-covered copper wire. Originally this was made in two layers, the wire being wound to the end and then back again on the first layer. Now it is made in six or more parallels, to which the primary current can be adjusted.

The whole of the primary and the core are placed in the ebonite tube, which is filled up with an insulating medium, usually hard paraffin.

Outside this is the secondary winding of thin, double, silk-covered wire. This wire is of increasing thickness toward each end of the coil, so as to obtain as much current as possible.

Some make this secondary in vertical sections of $\frac{1}{8}$ inch thick to build up the coil. One maker makes this secondary sectionless, that is, only one layer of wire between sheets of paraffin paper. This has to be wound in a horizontal position, a small roller preventing the wire overlaying. Another maker winds the secondary from end to end, always keeping to the proper number of turns and over each layer of wire, sheets of insulated paper are laid. Over all is laid a thin sheet of ebonite, and the ends of the coil covered with thick ebonite disks.

Coils are made to suit the voltage that is to be used, usually from the main up to 250 volts. They can also be made for as low a voltage as 20 volts, but probably the most suitable is 100 volts.

The current is direct but interrupted, and its action is to produce a secondary current at a very high potential; but compared with the ampèrage of the primary, of a very small milliampèrage, this latter being from ½ milliampère up to 25 or 30 milliampères, which would be considered a heavy secondary discharge.

A condenser made of sheets of tin-foil separated by a dielectric is necessary to obtain the required length of spark and current, except when the electrolytic break is used, when it is "cut out." The action is to take up current produced at the "make" of the interrupter so that it is discharged at the "break" of the interrupter, thus greatly increasing the spark, as the current produced at the breaking of contact is the one desired. So that when the interrupter "makes" a current flow in one direction, but on breaking it flows in the contrary direction and a surging current is therefore set up.

At the present time coils are made of such power that it is possible to obtain perfect radiographs by means of a single flash with the aid of an intensifying screen; such are the Dessauer Coil and Siemens.

The Dessauer consists of a very large coil, the whole of which is immersed in oil as an insulator. No interrupter is required, but a fuse fitted in a cartridge is in circuit with the primary. On switching on the current (about 80 ampères) the fuse (the thickness of which is properly gauged) bursts, and to prevent arcing is damped down. Hence a "breaking" spark is obtained. The weight of this apparatus is about half a ton.

The Siemens single-flash apparatus is a very large coil and the primary current is gradually let in and when at its maximum is suddenly broken, the spark (to prevent arcing) being blown out by compressed air. The advantage of a single flash must be obvious. The rapidity is such that

there is no blurring through movement, and also the anticathode being struck only once, instead of many times and never in the same identical spot, makes for perfect definition.

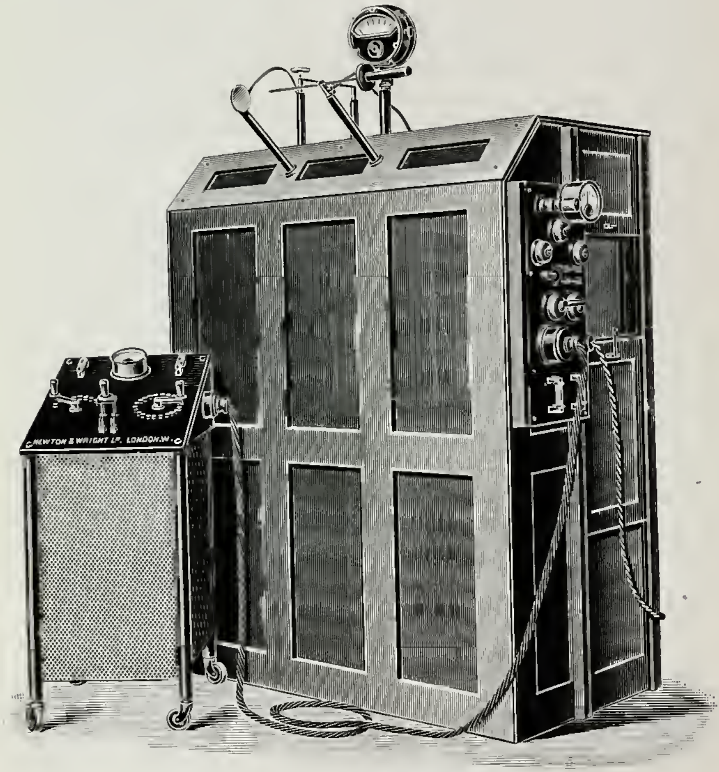


FIG. 62.—The "Snook" Röntgen apparatus.

But the Snook Röntgen apparatus is an entirely new departure and consists of a high-tension transformer, the alternating current of which is rectified by a high-tension commutator or reversing switch driven by the rotary converter which, if running from a continuous main, converts

the current from continuous to alternating. The practical result is a unidirectional current which is ideal for working, preventing gray negatives and also preserving the condition of the *x*-ray tube. It is also possible by means of a switch to obtain any desired current from 1 milliampère to 60 milliampères.

The Wimshurst Influence Machine consists of one or more pairs of glass (covered with a varnish of shellac) or ebonite plates on a single axle. In each pair the plates revolve in opposite directions and may be supplied with sectors or without. This machine gives a comparatively long spark according to its size, with a very small amount of current so that the Wimshurst is termed a static machine; but in America there are some Wimshurst's built on a vertical axle which will give as much as 15 milliampères. The use of static machines in this country is not wholly satisfactory owing to the humidity of the climate. To overcome this they are sometimes placed in glass cases, but then again these have their disadvantages. The static machine with all its faults has advantages over coils in that (while running) the current is absolutely unidirectional; is excellent for radioscopic work and—probably owing to the small amount of current—does not produce *x*-ray dermatitis. It is, however, of little use for radiographic work owing to the length of exposure.

Static currents possess therapeutic value in some cases.

Primary Current. This is now usually obtained from the main chiefly for these reasons: convenience, increased voltage, and quantity of current accumulators requiring so much attention as well as being an expense.

The supply from the main may be, however, continuous or alternating, and if the latter it must be rectified, *i. e.*, made continuous.

Continuous current in different parts of the country, unfortunately, may be supplied in various voltages. Also it is generated in some districts at as high voltage as 480 volts, which is reduced for lighting and other purposes in mains of 240 volts by means of the three-wire system.

This consists of having between the positive and negative wires a neutral wire, as shown by the following diagram:

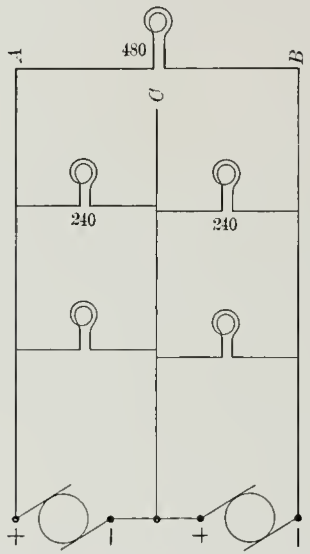


FIG. 63.—Diagram of three-wire system.

Now if current is taken from the mains A and B the voltage will be 480. But if a neutral main wire (C) is used (electrically) between A and B, and connections made between A C and B C then will the current between A C and B C be reduced one-half—240 volts. It is also necessary that an equal current is available on both sides when a large and sudden demand is made, as in switching on 20 or 30 ampères.

Alternating current must be rectified, and probably the most satisfactory method is by means of a motor generator, which consists of an alternating motor of the voltage of the main coupled to a continuous current dynamo of the requisite voltage and output in current.

These are made so that the sudden switching on of a large current to the coil is possible.

A very efficient rectifier is the Nodon valve, and it is possible to work a coil with it, but it is not so good as the above. It is made of an aluminium rod and a sheet of iron immersed in a solution of phos. sodii. This allows current to pass in one direction only, the reverse being dissipated in the solution as heat.

If current from the main is not obtainable then a sufficient number of accumulators and of such a size as will give the required current must be used. The writer has always found the Lithanode very reliable and portable as well as giving a large output. These can be easily charged from the main through a lamp resistance—of course, rectified previously if the current is alternating. If mains for charging are not available, then a small gas engine or motor dynamo (direct shunt wound) should be used. Or, again, if the latter is not to be had then they can be charged by a battery of gravity ($CuSo_4$) primary cells, bearing in mind that each primary cell has a pressure of only about 1 volt, whereas each accumulator cell has a pressure of about 2 volts, and also it is necessary to have a greater voltage in the primary battery than in the accumulators by about $1\frac{1}{2}$ to 1 volt.

The amount of current given off from the primary cells is small.

If the *x*-ray worker cannot have any of the foregoing means of obtaining primary current, then primary batteries, such as Grove's or bichromate, are the only resort, but these give the maximum amount of trouble and annoyance apart from greater expense, so much so that the writer would strongly advise them not to be used.

Interrupters or Breaks.—The interrupters for breaking the current in the *x*-ray coil may be divided into (1) mechanical and (2) electrolytic.

The Hammer Break was the first and acted in the same manner as the hammer of an electric bell. It is now quite obsolete.

The Vril was an improvement on the hammer break in allowing more current to pass into the primary coil, but it was somewhat slow, and noisier than the hammer.

The Dipper Break consists of a wire worked by an electro-motor which dips in and out of mercury, thus making and breaking the current. The mercury is contained in a glass vessel with either methylated spirits, paraffin or gas as an electrolyte. In working, the mercury is apt to become foul by reason of a mud which forms, although if an iron vessel is used much less mud results, consequently less cleaning is necessary. To recover the greater portion of mercury from this mud it is advisable to place it in a large dish to allow evaporation of the electrolyte. No mud is formed with coal gas as electrolyte.

This break is only suitable for low voltages—say 20 to 50, but it can be used up to 100 and will pass a current up to 20 ampères or so. It is somewhat noisy to use. Either large or small currents are obtained by adjusting the vessel so that the dipper will go more or less deeply into the mercury. At starting it is necessary to speed up the motor before switching on the primary or short circuiting may ensue, and also to switch off the primary current before stopping the motor.

The Mackenzie-Davidson Break is quieter. It consists of a large quantity of mercury in a box, into which at the surface, fans revolve on an axle from a motor inclined at an angle with the surface of the mercury. The same electrolyte is used as for the dipper.

The Jet Interrupter is also a mercury break in which a jet of mercury strikes a metal tooth. Some are made where the mercury is pumped up by a centrifugal pump, the jet produced by the revolution of the pump, causing it to make contact with the tooth and on breaking, sets up a current. Others are made where the teeth revolve and the jets of mercury issue from the side of the containing vessel. The same electrolytes as for the others may be used. It is worked by means of an electro-motor or it can be worked by hand. It is a very satisfactory instrument,

the old objection of clogging of the jet holes being obviated. It can be used for currents of 20 ampères or more and up to 240 volts.

The Sanax Interrupter is made on an entirely different principle from any of the others. In this a steel pear-shaped vessel is attached to the vertical axle of an electro-motor and contains a small quantity of mercury with paraffin as the electrolyte. Centrifugal force causes the mercury to rise up the sides of the bowl until it reaches a groove. Thus a ring of rotating mercury is formed. Inside the bowl on a vertical spindle placed eccentrically is a fiber disk with 2 copper segments rotated by the mercury ring which makes and breaks the current. This form of break makes very little noise and has many advantages.

The Auto-Magnetic is very efficient and gives little or no trouble. Briefly it consists of a vessel partly filled with mercury, and coal gas as an electrolyte. In this vessel is a horizontal axle fitted with blades which on revolving sweep in and out of the mercury. No motor is used but a series of field magnets, so that on switching on the current the blades revolve instantly, through the action of the field magnets. Unlike some others on the same principle it can be easily made to travel either very rapidly or slowly and also regulated to give from ½ milliampère in the secondary up to 25 milliampères.

The Electrolytic Interrupter consists of a large glass vessel partly filled with dilute sulphuric acid (sp. gr. 1200) into which dips a sheet of lead (cathode) and also a platinum wire (anode) fitted into a porcelain holder. The platinum emerges from a hole at the extremity of this holder about a quarter of an inch or so. On switching on, the current flows from the platinum point to the lead by reason of the conductivity of the electrolyte and in doing so bubbles of hydrogen form on the surface of the platinum thus breaking the current but only for an exceedingly short time. The bubbles breaking off again, the current again flows when the same action takes place again. The advantage this break has over others is its rapidity and the great amount of cur-

rent that can be passed. One, two, or three anodes can be fitted either to work together, or as a single or double pole. The disadvantage of this break is the liability to reverse current which heats and spoils the x-ray tube. Although it can work from any voltage from 50 to 250, yet probably 100 volts is the best. It also makes much noise but this can be lessened by placing it in a sound-proof box, or attaching a rubber air cushion to the porcelain tube.

Switchboard.—When two kinds of interrupters are used, as a mercury and electrolytic, a change-over switch is necessary and this is attached to the switchboard or table. The necessity arises from the fact that with a mercury break the condenser is used in the coil, but if an electrolytic break is used, not only must the current be changed over it but also the condenser, not being used, must be "cut out." With this latter a large current may be put through the coil, and in the experience of the writer the best switch for satisfactorily breaking the current without any fusing of the contacts is the rapid switch made by Butt, which by one movement of the lever enables the operator to make an exceedingly rapid exposure or one as long as desired.

Ammeters for measuring the current should be used, but voltmeters are not necessary. To measure the secondary currents milliammeters are necessary, as without one the amount of current passing through the tube is not known and the correct exposure a matter of guesswork. These are usually fitted with shunts, thus multiplying the reading of the index, because with a mercury break possibly only 2 milliampères may be passing, but when one of the modern mercury breaks, taking a large current, or the electrolytic, is used, as much as 20 to 30 milliampères or more may be passed through the tube; a much higher reading is therefore necessary.

The Spinctermeter is the name given to the instrument formerly known as the spark gap, and consists of a pointed rod which can be pushed near to or drawn away from a ball or disk and measures the alternative spark gap. This

shows arbitrarily (for it varies according to the apparatus and amount of current passed) the resistance or penetrative power of the tube.

The scientific and accurate measurement is obtained by the use of a radiometer, of which there are several. Benoist's consists of an aluminium disk graduated in steps, having in the centre a thin silver plate. This is viewed through the fluorescing screen, and when one of the aluminium steps has about the same transparency as the silver, the hardness or penetrative power of the tube is seen by the number of that step, so that a tube can be described as being of the hardness of, say, "No. 8 Benoist."

X-RAY TUBES.—These may be divided into three classes;

1. Heavy anode.
2. Light anode.
3. Therapeutic.

The first kind (H. A.) is for taking rapid exposures, and some of them are described as being extra heavy, while the L. A. is meant for currents of 2 or 3 milliampères. But as a matter of fact these L. A. tubes will sometimes withstand for a third- or a half-second 20 milliampères, the writer having had experience of at least three L. A. tubes which gave several hundred such exposures.

The third class, as their name implies, are solely for therapeutic work, giving off abundance of rays but not having the cathode and anticathode adjusted for focus.

X-ray tubes are made by several makers both in England and on the Continent, each maker having some special method of manufacture.

Müller Tubes are made for long life and if strained too much, especially when new, the vacuum will get low. Automatic regulation devices are attached.

In the Bauer Tube the chief feature is the valve for lowering the resistance. An infinitesimal quantity of air being admitted as desired.

Some tube makers, as Cossors, attach to the tube an automatic device for lowering, whereby CO_2, instead of air, is liberated into the tube. To keep the anticathode cool the

rod holding it is prolonged to the outside and fitted with metal radiators so as to cool it by contact with the air.

Another method is to have water in contact with the back of the anticathode, and another: copper tongs are inserted close to the anticathode and can be withdrawn and plunged into water to cool.

The oscilloscope tube is employed to detect any trace of reverse current, and consists of a cylindrical exhausted glass tube about 8 inches long by $1\frac{1}{2}$ inches in diameter, containing 2 aluminium wires of equal length nearly touching, with a disk of mica in the middle of the tube having a central hole. If the current is unidirectional a blue fluorescence is seen about the wire in one-half of the tube, but if any reverse is present the fluorescence is seen more or less on both wires, showing the amount of reverse current.

DENTAL RADIOGRAPHY.[1]

The variety of uses to which the Röntgen ray has been put in the profession of dentistry has assumed such dimensions, especially since the outbreak of the war, that but little justice can be done to this all-important subject in the comparatively small space that can be devoted to it in this work.

The question as to the intimate causal relation of many diseases of hitherto supposed obscure origin and foci of infection caused by pathological conditions of the apical regions of the teeth, has of late become such a vital one, and the aid afforded by dental radiography has been recognized as so essential, that an extensive work on this subject would represent a large volume, to say the least.

For a more exhaustive study of this valuable addition

[1] By Dr. C. H. Abbot of Berlin. (In the revision of this chapter the writer has had to contend with the very serious disadvantage of being deprived, through the vicissitudes of war, of his own notes, films and other data. He has therefore been obliged to gather some of his material from various outside sources and is indebted to his colleagues for many hints and suggestions. Especial thanks are due to Drs. Ottolengui, H. F. Hamilton, A. I. Hadley, G. M. Brown and to Mr. J. J. Lowe for furnishing a number of films for illustration.)

to dental science the reader is therefore referred to those works which treat on that subject exclusively. Such works comprise, among many others, the Atlas by Prof. Dieck,[1] a pamphlet by Port and Peckert,[2] works by H. R. Raper, Rollins, Williams, Pfahler, Tousey, Cieszynski, Price, Cryer, Sydney Lange, Van Woert, Rhein, McCoy, Shenton, Weski and many others.

The writer hopes, however, by the following sketch of the various applications of this branch of electricity in dentistry, to incite the profession to its even more extensive adoption.

This hope is indeed in a fair way of being realized since the publication of the first edition of this work; for what dentist would now consider himself "up-to-date" and abreast of the times who did not either own his *x*-ray outfit or who was not in touch with an *x*-ray specialist to whom he sends his patients for radiography. The most important factor of "checking up" his own work, makes the presence of an outfit in the dentist's office the more desirable, as, especially if in verifying his root-canal work, the making of several radiographs at short intervals should become necessary, the patient would naturally object to several visits to a specialist on the same day. In cases of a more complex nature, however, in which only the experienced specialist can produce a serviceable radiograph, also in many cases requiring plates, or in case of doubt as to the reliability of his own film, the dentist can always refer the patient to a specialist for comparison.

The properties and production of the rays are described elsewhere in this work.

The following description of the appliances connected with the technic of dental radiography may provide some useful hints to the operator for obtaining the best results. One of the most important considerations is the determination of the resistance or vacuum of the tube, and for this purpose a number of appliances have been devised, such as

[1] Archiv und Atlas der normalen und pathologischen Anatomie in typischen Röntgen Bildern. Anatomie und Pathologie der Zähne und Kiefer im Röntgenbilde.

[2] Ueber die Röntgenphotographie in der Zahnheilkunde.

the Walter and Benoist scales, Wehnelt's cryptoradiometer, Beez's scale and Bauer's qualimeter, by means of which the resistance of different tubes can be gauged, given the same ampèrage and voltage of the current prior to its entering the tube.

It is well to bear in mind that the more current is sent through the tube the harder or higher it will register on the scale, so that in determining its resistance, the same strength of current should always be taken as a base of calculation. Another means of determining the so-called hardness of a tube is to measure the length of the spark gap on the induction coil at the point where the spark can just jump the space between the two poles, and then to separate these poles far enough to prevent the current from doing so. This distance if determined beforehand—given a certain strength of current measured in milliampères—will register the requisite resistance of the tube.

If, for example, a tube is best adapted for certain dental uses, when "backing up" a spark of 7 inches at 5 milliampères, it will be too hard if it backs up a spark of 8 inches and too soft if it does one of 6 inches.

There are in the United States many excellent *x*-ray outfits, and the dentist who wishes to equip himself will, by studying the various advertisements in the dental magazines, easily find something to meet all his requirements.

Mention of the Coolidge tube, which has attracted so much attention among *x*-ray specialists, should not be omitted here. It does away entirely with the regenerating process necessary in all other tubes and has the further advantage of allowing the operator to control voltage and ampèrage irrespective of each other.

The vacuum is estimated to be about 1000 times lower than in other tubes and remains constant. The anode and anticathode or target are identical and consist of a piece of tungsten attached to a rod of molybdenum; the cathode consists of a spiral of tungsten wire enclosed in a tube of molybdenum which projects slightly beyond the spiral and serves to focus the electrons onto the target. The cathode

is heated either by a storage battery in connection with rheostat and ampèremeter, or from the main current by a separate generator with ammeter, to control the amount of heat passing through the spiral and consequently the degree of penetration which is indicated by a secondary voltmeter. The amount of current is controlled by rheostat and indicated by milliammeter. The tube operates without fluorescence and practically suppresses any current not flowing from anode to cathode, hence it does away with all rectifying devices. As will be gathered from the foregoing, this tube necessitates the installation of special apparatus which makes the preliminary cost considerable, but its life is claimed to be unlimited.

The writer is not familiar with the English outfits, which are no doubt excellent, but respecting which he has no means of information at the present time.

The human hand was at first most frequently used for the determination of the resistance of the tube, as it was very convenient and afforded a most reliable means for the purpose to the experienced operator. But the disastrous results of this method, which was long in use before the danger was realized, are now too well known to require further comment. "Skeleton" hands have been used in dark boxes with a fluorescent screen similar to the Wehnelt scale, and Dieck has devised a cryptoscope containing a section of the lower jaw with teeth, encased in wax so as to imitate approximately the density of the surrounding soft tissues. These have proved very efficient in general use.

The resistance most adapted to general dental work is about 6 to 6½ on the Wehnelt cryptoradiometer (6 to 6½ Wehnelt for short). One of the advantages of the Wehnelt is that there is no need for darkening the room, as the padded box can be pressed close to the eyes so that no disturbing light is noticeable. It has one disadvantage, however, in that the subjective or personal element gives rise to discrepancies, as human eyes do not all see quite alike, and differences of impression of as much as 1 to 2 units have been registered by the same tube. The proper resistance of the

tube depends upon the thickness and density of the object to be x-rayed; for example, a radiograph of the whole skull would require a tube with the resistance of about 9 to 10 Wehnelt.

The writer has found the Bauer qualimeter used under the above-mentioned conditions a most reliable and satisfactory stand-by, for it does away with the more or less difficult comparison of shades, and registers the condition of the tube in plain numbers. This, as well as all other methods, however, has a slight drawback, inasmuch as it takes some few seconds for the indicator to cease oscillating and to point to the number in question, thus permitting the tube to grow a trifle "harder" by virtue of its longer use, but with a little experience, the observer will be able to anticipate the eventual point of rest.

The following table compares the principal scales:

Bauer .	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10
Wehnelt	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15
Walter	1.0	1–2	2–3	3–4	4–5	5–6	6–7	7–8		
Benoist	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10

When the operator is in a position to direct the rays in a straight line through the middle of the cylinder with the aid of the centralizing telescope or "pointer" the next question he must consider is the relation of this line: (1) to the axis of the tooth or root, and (2) to the plane of the film or plate; and here he must observe certain principles of projection which in themselves are simple, but which it may be well to recall.

The first is the consideration of the relative distances between the target, the object to be x-rayed and the film or plate, and the effect of these upon the size of the skiagraph compared to the object itself. This may be easily illustrated by the accompanying diagrams, and roughly stated by the following self-evident rule.

T being the target, cd and c_1d_1 the object to be x-rayed,

and p the film or plate, the nearer the object cd is to the plate, the smaller the image ab will be, and the farther from the plate, the larger the image c_1d_1 will be on the plate a_1b_1; the distance from T to the plate remaining the same, the image of the object will be larger, the nearer the target is to the plate; ab produced by the rays starting at T is longer than a_1b_1 with the target at T_1.

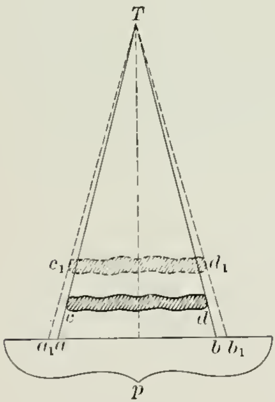


Fig. 64

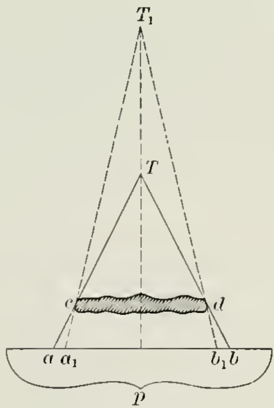


Fig. 65

The distance between the target and the plate or film in dental radiographs should usually be about 35 cm. with the film pressed as closely to the alveolus as possible. In taking radiographs of the teeth of the upper jaw, with the plate or film held between the teeth and taken from above, the distance should not be less than 35 to 40 cm.

The direction of the rays in their relation to the axis of the roots (especially in the upper teeth) and the plane of the film is of great importance in producing an approximately correct image of the tooth or root on the film, and here the rules advocated by Cieszynski and Dieck should be observed as closely as possible, provided there are no other conditions, such as can only be brought out by a distorted picture; this, however, will be referred to later.

The rule to be observed is to direct the rays vertically through the apex of the root in question onto an imaginary

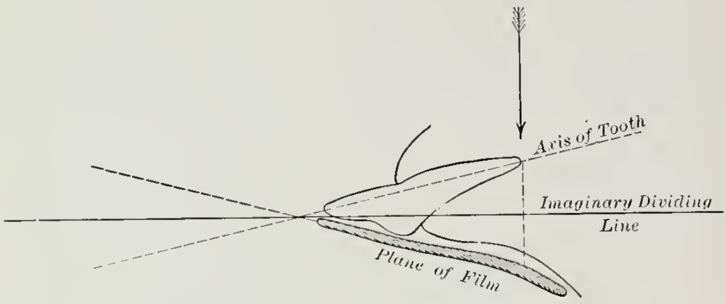


Fig. 66

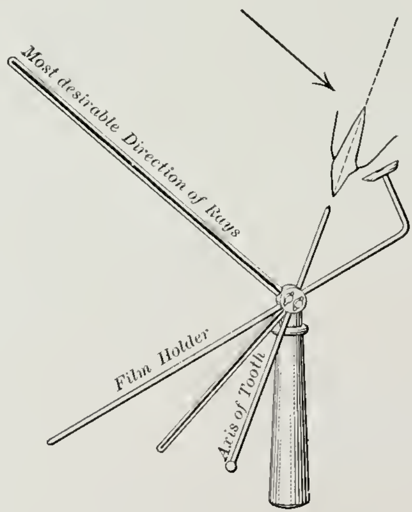


Fig. 67

line dividing the angle formed by the axis of the root and the plane of the film. This is shown in Fig. 66.

An instrument devised by Dieck for this purpose is shown in Fig. 67.

The more the rays are directed from above, the more foreshortening of the tooth will occur, and the more from below, the more elongated the teeth will appear on the film.

Occasionally it may be important to procure an exact measurement of the length of a root, which can easily be ascertained provided the operator can insert a broach of a given length into a part of the canal before exposure. This can be calculated by the following proportion:

If the length of our broach ab is known we can measure on the radiograph the length of the image of the root $a'c'$, also of the broach $a'b'$. The actual length of the root to be calculated being x we have the proportion:

$$a'b' : ab = a'c' : x$$

$$x = \frac{ab \times a'c'}{a'b'}$$

or, for example, if $ab = 6$ mm.

$a'b' = 8$ mm.

$a'c' = 10$ mm.

we have $8 : 6 = 10 : x$

and $x = \frac{6 \times 10}{8} = 7.5$ mm.

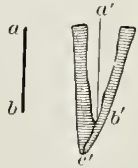
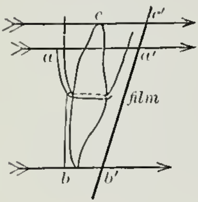


Fig. 68

For determining the length of the roots of vital teeth or those that cannot be entered by a wire, Ottolengui has devised a clever means of measurement. It consists in winding a wire around the neck of the tooth in question, allowing one end to extend to the occlusal or incisive surface, and the other outside the gum as nearly as possible in the direction of the axis of the root. By taking a radiograph with the wire applied

in this way and measuring on the film the length of the tooth in relation to the wire attachment, and this again to its actual length, a fairly accurate measure of the root from the horizontal portion of the wire to the apex can be obtained.

See Fig. 69 and equation.



$$x = bc$$

$$a'b' : ab :: b'c' : x$$

$$x = \frac{ab \times b'c'}{a'b'}$$

or for example:

$ab = 15$ mm.
$a'b' = 16$ mm.
$b'c' = 18$ mm. $\quad x = \dfrac{15 \times 18}{16}$

$$x = 17.8 \text{ mm.}$$

Fig. 69

This of course will not be quite correct in case of a labio-palatal or lingual curvature of the root.

One of Dr. Ottolengui's colleagues having expressed a doubt of the accuracy of this method, on account of the distortion produced by taking pictures at various angles,

Fig. 70

Fig 71

Dr. Ottolengui decided this matter as follows: Taking a dried skull, he placed a wire around the tooth neck at exactly one inch from the apex and then took the pictures at extreme opposite angles. The illustrations show the resulting radiographs. Computed by one of these, the tooth was shown to

be $\frac{101}{100}$ inch in length and computed by the other, it was shown to be $\frac{99}{100}$ inch in length. In each instance, therefore, the variation from the truth was $\frac{1}{100}$ inch. As the knowledge of the length of a living root is usually required only to determine whether there is enough root to carry a crown or bridge abutment, it is seen that this method is sufficiently accurate.

In taking *x*-rays of teeth in the lower jaw the placing of the film is comparatively simple for the incisors, bicuspids, and molars; for the canines, owing to their occupying a more or less "corner" position in the arch, the holding of the film is not always a simple matter, for unless it is very narrow it will bend a great deal, causing considerable distortion, especially of the adjoining teeth. In cases where it is desirable to include the apex of the roots and the parts underlying them, especially in lower wisdom teeth, the operator often encounters a good deal of opposition on the part of the patient, on account of the irritation to the soft tissues caused by the wrapping of the film. A film-holder which obviates this difficulty is described in another part of this chapter.

In cases where the formation of the lower jaw is such that it is difficult or impossible to obtain a view of the apex, or parts underlying it (as for example an abscess cavity or cyst) without distortion, it will be well to direct the rays considerably from below in order to include these portions, although this will produce a somewhat distorted image. But where it is a matter of locating an abscess-cavity or cyst, this is of no consequence compared to the establishment of the point in question. (Fig. 72.)

The interpretation of the film or plate is naturally fully as important as its production, and it should be kept in mind that what is seen is the effect of the difference of absorption which the rays undergo in their passage through the tissues which they penetrate. This again depends on the density and thickness of the object, or the combined densities and thicknesses of superimposed layers of different structures such as roots, bone, pus, filling materials, etc. For instance, the overlapping part of a buccal molar root over part of a

palatal one, might give to the unobserving a misleading picture, when proper reasoning will put the operator right. The designation "positive" and "negative" in works on the Röntgen ray is often a little confusing. In most text-books the illustrations consist of prints of the films, while in practice the operator generally uses the original film itself. On the latter the teeth and bones show light, and the softer tissues and cavities appear dark, as they offer the least resistance to the passage of the rays; on the former, of course, the reverse is the case, and as the prints or positives are generally used as illustrations in the text-books, the respective shadows will be referred to as they appear in these positives, unless otherwise expressly designated.

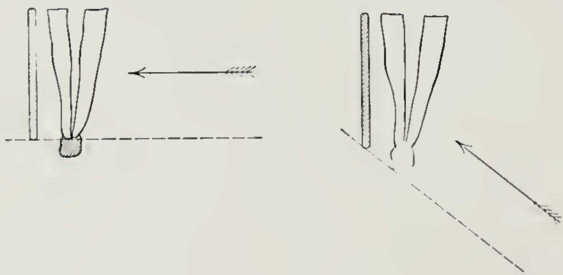


Fig. 72

Ottolengui has very logically suggested the standardization of the terms:

(*a*) Radiopaque (radiopacity) from "radius" a ray, and "opacus," impervious to light,

(*b*) Radiolucent (radiolucency),

(*c*) Radioparent (radioparency),

which two last expressions bear the same relation to each other as "translucent" and "transparent" and are readily intelligible.[1]

This would do away more or less with the term "rarefied" in the reading of radiographs which is often misleading and

[1] See Dental Items of Interest, February, 1917, p. 141.

denotes rather a pathological condition, whereas the word "radiolucent" is simply the statement of a physical condition, which may or may not imply a diseased bone area. It may be caused by the presence of a foramen or by apicectomy (or root amputation). The term "Radiodontia" suggested by Raper commends itself to the writer as terse and comprehensive.

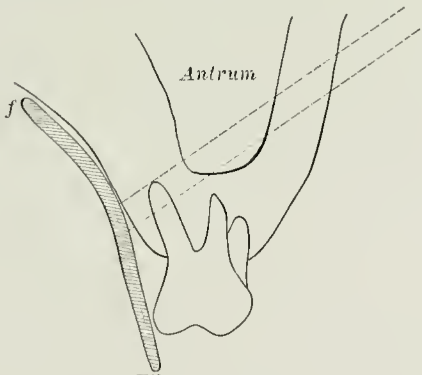


Fig. 73

In the interpretation of radiographs there are several anatomical points to be recalled, the neglect of which might at times be the cause of a misleading diagnosis. One source of error may be a small dark spot on the film caused by the anterior palatine foramen, which may be mistaken for destruction of bone resulting from abscess. The mental foramen also may give rise to the same faulty diagnosis, although more rarely, owing to its lower position in the inferior maxilla. The canal of the inferior dental nerve may also be mistaken for a diseased condition of the bone.

The suspicion that molar or bicuspid roots may be projecting into the antrum is also often suggested to the operator by the appearance of the film, and a correct diagnosis may be very difficult without accurate observation and reasoning. If the topography of the antrum is considered in its relation

to the roots of the molars and bicuspids and the hard palate, it will be easily understood that owing to the slanting direction of the rays from above downward, one or more roots of the above-named teeth are often projected into the image of the antrum. Of the molars this is most frequently the case with the palatal root (Fig. 73). The question of perforation of the floor of the antrum by a diseased root requires a very sharp radiograph, marking the contrasts very clearly and showing whether the pericementum and periosteum of the alveolus are intact or not. The walls of the alveolus will show as a thin white line (linea dura or alba) on the film, and the space occupied by the pericementum as a dark line. In any case presenting the least doubt two or more radiographs from different directions or stereoradiographs should be taken. Portions of the antrum itself may be mistaken for a diseased condition of the maxilla, a granuloma or cyst. There may also be a confusion of the lower symphysis of the malar bone and a wall of the antrum in the reading of radiographs. When using a rather soft tube the nares may also be mistaken for "rarefied" areas of bone, a point to be considered. In every case when interpreting a film we should not only consider the immediate area under suspicion but compare the appearance of the bony tissues at that place with all the surrounding structures of the other teeth and roots on the film.

For viewing radiographs a number of illuminating boxes containing two or more lamps have been put on the market which enable the operator to examine the films by different degrees of light by varying the number of lamps or regulating the current by a rheostat, for different parts of the same film may not show to equal advantage under the same light conditions. Generally it is best to view the film against ground glass or opaque celluloid. On dull days a light gray sky may also serve as a good background.

The question as to which one of two (or more) teeth or roots partly lying in the line of the rays is before or behind the other, is one which may also arise in practice. This may not be an easy matter to decide without the aid of stereo-

scopic radiographs, but the tooth which appears relatively the smallest and most sharply outlined will obviously be the one nearest the film and consequently nearest the palate in the superior maxilla, or if they are lower teeth, nearest the lingual wall of the mandible.

The proper time of exposure is of the utmost importance in obtaining satisfactory results in x-ray work. Here again it is very difficult to advise the beginner, as so much depends upon the strength of the primary current, the size of the induction coil or whatever apparatus the operator is using.

With a coil furnishing a 40 to 50 cm. spark, and a primary current of 25 to 35 ampères and a tube of approximately 5 or 6 Wehnelt (units) the operator should under ordinary conditions obtain excellent results with an exposure of from six to eight seconds, unless the bone is exceptionally dense, when a somewhat longer exposure should be made. The time for taking the lower molars (especially second and third) should be about double that for the front teeth, owing to the greater thickness of the bone to be penetrated. Practice will be the best teacher in this respect. Less powerful outfits will necessitate relatively longer exposures.

For those who can afford interrupterless or the Coolidge tube outfits, the time of exposure is of course proportionately shorter and in many cases may be cut down to a second or even a fraction thereof, but generally a little longer exposure with correspondingly less strength of current will give more satisfactory results. For nervous patients or children, or in cases where the insertion of the film at the back of the mouth is liable to cause choking or nausea, the possibility of cutting down the exposures to that extent is a distinct advantage which can be readily understood.

The operator working with a more modest outfit has also a means of abbreviating his exposures, viz., by using the so-called intensifying screens with his films. This screen consists of card-board covered on one side with a preparation containing principally tungsten or wolfram which fluoresces and absorbs the x-rays to a marked degree, acting on the film or plate for some time after the exposure; it is therefore

undesirable to leave the plate packed with the screen long, for fear of causing overexposure. One drawback with these intensifiers is that they are liable to fog the radiograph to some extent and that they do not keep very long without losing some of their strength. Still, when we consider that they are capable of reducing the time of exposure at least tenfold, we cannot but acknowledge that they certainly should have their place in every outfit. The screen is best applied by packing it with its glossy side facing the sensitized side of the film.

The intensifying screens are of especial value in the taking of glass-plate radiographs, involving the whole or parts of the skull, as the longer exposures will of course raise the resistance of the tube to a considerable extent, a factor which is particularly undesirable in stereoscopic work, for the regeneration of the tube between the first and second exposures should be avoided for obvious reasons.

Stereoscopy in Dental X-ray Work.—It is easily understood that *x*-ray stereoscopy differs from ordinary stereoscopy, inasmuch as the exposures are made consecutively with the same tube, which is moved a certain distance from either side of the position from which the simple *x*-ray would be taken. The plane, of course, must be the same and the film or plate must be placed in the same position for the second that it occupies during the first exposure. A stereoscopic tube with two cathodes and anticathodes, the focal centres of which are placed 5 to 6 cm. apart, has been devised by Fürstenau, but this seems hardly necessary when the operator has a stand equipped with a graduated scale upon the horizontal arm.

In this connection it will be well to bear in mind that stereoscopy is not to be depended upon for furnishing absolutely correct relations of the different parts. This conclusion is amplified by the fact that there is so much diversity of opinion among different authorities as to the proper distance to which the tube should be moved away from the median line for the two exposures. The distance should approximate that of the eyes from each other. Some say that this should

be 6, others advise 7 cm. Marie and Ribault have published a table giving a number of different figures[1] varying from 2 cm. to 10 or even 16 cm. for the displacement of the tube in x-ray stereography, according to the distance of the part in question from the anticathode, and the thickness of the object. This does not appear very rational, as the distance separating the human eyes does not vary to such an extent. Albers-Schönberg,[2] as well as Kells,[3] in their works describe a complicated apparatus, giving to the tube not only a lateral but a rotary displacement for the most powerful rays to pass through the object to be stereographed. But this seems to the writer unnecessary, as the rays spread fan-like from the target, and those striking the object, although not the most central ones, still are strong enough to produce excellent results.

Nevertheless the stands for stereoscopic work are to be recommended to those who can afford the expense, especially where larger areas are to be taken. The rotary (or converging[4]) movement of the focussing cylinder allows the whole area to appear on both pictures, whereas by moving the tube laterally a part of each image which is circumscribed by the preliminary focussing upon the principal point of interest would become obliterated by the corresponding wall of the cylinder. This may in a measure be compensated by the use of a cylinder of larger diameter, which, of course, admits a greater number of secondary rays.

These diagrams will show that in Fig. 74 only the middle part of the object will appear on both exposures, whereas in Fig. 75 the whole object appears in stereoscopic projection by either of the two methods employed. In the case of Fig. 74 the whole object nevertheless appears in the stereoscope; only the middle part, however, is really plastic.

For stereoscopic radiography with plates, sliding plate holders have been put on the market enabling the inter-

[1] Archives d'Electricité medicale, July 15, 1899.
[2] Die Röntgenteehnik.
[3] Dental Cosmos, July, 1912.
[4] Kelly-Koett stand used by Ivy, of Milwaukee, see Cosmos, July, 1917.

change of plates without disturbing the position of the patient. Both plates are placed in the holder simultaneously, the one being covered by a sheet of heavy metal during the exposure of the other. Both plates should be developed together for the same length of time in order to produce the most uniform appearance.

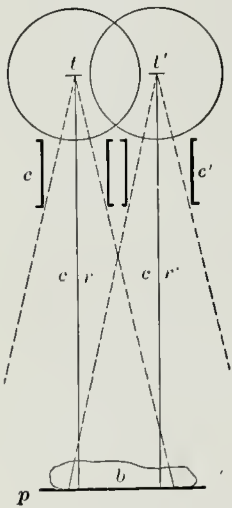


FIG. 74.—Lateral movement of tube (cylinders parallel). *b*, body to be *x*-rayed; *p*, photographic plate; *t t'*, target; *c c'*, cylinder; *cr*, *cr'*, central rays.

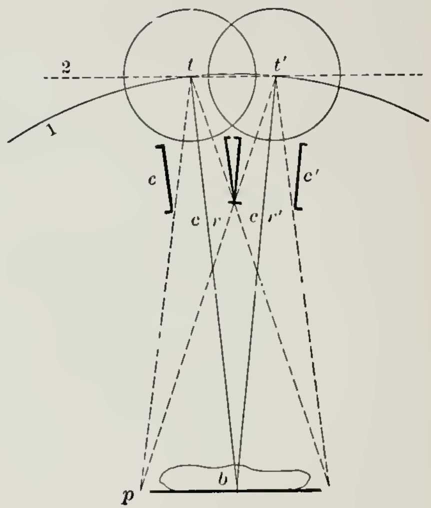


FIG. 75.—*1*, rotary movement of tube (cylinders converging); *2*, lateral movement of tube (cylinders converging).

The distance from target to film or plate should not be less than 35 cm.; for the whole head it should be at least 50 cm.

The plates can be viewed in the Wheatstone Stereoscope, in their natural size, or after reducing, in any hand stereoscope. Various ingenious devices for localizing foreign bodies in the head and body have been invented in connection with stereoradiography, which have proved of inestimable

value during this war, in cases of gunshot wounds, for determining the position of bullets and fragments of shells, etc.

A few years ago there was considerable discussion about the feasibility of examining the teeth with a fluorescent screen, or taking radiographs with the anticathode of a tube of suitable dimensions and construction inside the mouth. Tousey tried these tubes, also Guye, of Geneva, and Bauer, of Berlin, but these methods were soon abandoned on account of the very considerable danger to the patient. The idea of simply placing a little tube in the patient's mouth, holding the plate wherever desired and turning on the current, is very alluring, but other considerations make it appear less so, especially the prospect of the patient sustaining severe burns for which the operator is responsible.

Extra-oral exposures in which the film or plate is held outside of the mouth, often become necessary when larger portions of the maxilla or other bones of the head are involved. Here the operator will do well to refresh his memory in regard to the topographical anatomy of the head and neck, as the overshadowing of the parts to be examined by various other portions of bone may give rise to many errors in diagnosis.

In taking extra-oral radiographs of the teeth, the parts especially desired to be brought out should rest as near the plate as possible. Care should be taken to avoid the projection of the styloid process to confuse the image. For bicuspids and molars the rays should be directed to pass between the ascending ramus of the mandible and the vertebral column. The mouth should be closed and the head tilted so as to avoid bringing the opposite side of the mandible onto the picture. For the front teeth the rays should be directed from behind, the patient leaning well forward. Experience and a knowledge of topographical osteology of the head will be the best teacher in this by no means simple technic.

It is rarely possible to obtain a large radiograph of this kind without distortion of some part or other, but that does not necessarily make it any less valuable, as in most cases the necessary allowances can be made to arrive at correct con-

clusions; but where it is possible to avoid such a condition it is preferable to do so. For this purpose a "phantom" skull attached to a stand has been devised by Dieck, which is placed so that the centralizing telescope of the protective box containing the tube may be occupied by the patient's head during the exposure.

The tedious process of cutting and wrapping the films has been superseded by the manufacture of ready-packed *x*-ray films of various sizes, rapid and slow, and obtainable through most dental firms. A number of ingenious devices have been thought out for holding the film in place in the mouth. Among others, a hardened Stents impression, trimmed to suit the needs of the case, has been recommended. Cieszynski has constructed film-holders for the upper and lower jaw, the upper one consisting of a metal frame to be held in position by the bite of the patient, aided by the use of a rubber bag to be inflated after the film has been inserted. The writer, however, considers that up to the present nothing surpasses the human finger as a film-holder for general use, and were it not for a certain danger to the operator or the assistant who lends his hand to this purpose, this simple method would be the best.

Ottolengui recommends the use of a rubber dam clamp for holding films in the mouth, a suggestion that commends itself especially where the radiopacity caused by the clamp does not collide with the object in view, as would be the case with pulp stones.

Danger of X-ray to Patient and Operator.—As regards the patient, the danger of *x*-rays can be very readily dismissed from the mind so far as radiographs are concerned, for the exposures, even the longer ones, are now too short to do even a child the least harm, unless the operator is guilty of the grossest negligence. It is nevertheless desirable, especially in the interest of the operator, to observe a few precautions so as to avoid being held responsible, even for imaginary burns or skin troubles due to other causes. It is well to introduce a cowhide or an aluminium filter, the latter of 2 mm. between the tube and the patient's face, as the soft

or superficial rays that are the principal cause of injuries to the skin, are absorbed without impairing the clearness of the radiograph. In the case of an accusation on the part of an imaginative patient, the proof that the operator used these precautions would help to exonerate him in the eyes of the law. A rubber cloth or apron laid about the patient's shoulders would also act as an insulator for sparks or effluvia emanating from the wires or metallic parts of the tube that might cause an unpleasant shock to the patient without probably doing him any harm. The more even the semblance of carelessness can be avoided, the greater will be the patient's confidence and appreciation. To "make assurance doubly sure" an insulated grounding wire or chain should connect the metallic parts of the stand that come in contact with the tube to a gas or water pipe in the office.

The danger, however, is immeasurably more serious in the case of those who occupy themselves with this work extensively. It has been stated before that the hand should never be used as a means of testing the tube, and the bare fingers only in the rarest and most urgent cases, where a protective glove is too bulky. This glove should form part of every dental *x*-ray outfit, and can be purchased at the regular *x*-ray supply stores. These gloves are made of a protective material consisting of thick rubber cloth impregnated with metal, and are well-nigh absolutely impervious to the rays. A compromise between a glove and a mitten has been used in the writer's surgery for some years and has given much satisfaction. It consists of a thumb and forefinger, and a casing for the other three fingers together; it is somewhat clumsy, but serves to hold the film well in place when once the same has been properly inserted *without* the glove, which can be slipped on while the film is temporarily held with the other hand. Tousey mentions another way to make protective gloves: Soak thick leather gloves in a saturated solution of bismuth chloride, then immerse in cold running water for an hour; repeat three or four times. This method is published by Dr. William Mitchell, *Archives of the Röntgen Rays*, April, 1908. It goes without saying that the same

precautions used by the x-ray operator for his own protection should be employed for his assistant, and in all cases where the film can be held by the patient himself or by artificial means, both operator and assistant should disappear behind a good-sized lead-glass screen during the time of exposure.

The question of secondary rays is one of such importance that it must be touched upon here, for not only do these rays expose the operator to a certain amount of danger but they impair the clearness of the radiograph.

The impact of the primary Röntgen rays upon any solid or liquid body gives rise to rays which are called secondary; they radiate in all directions from the point of impact and act similarly to reflected rays; consequently they may to some extent be dangerous to those exposed to them, although they are not as powerful as the primary rays and possess certain properties that differ from them.

The other disadvantage of these secondary rays is their effect upon the sharpness of the image on the plate. They arise from contact with the wall of the tube and are more or less cut out by the lead cylinder attached to the stand (Fig. 76), but this does not do away with the seeondary rays originating in the body itself whieh is to be x-rayed, for these are beyond the pale of the cylinder, and their effect could only be eliminated by interposing another cylinder of suitable dimensions between the object and the sensitive plate (Fig. 77). But such a one, with a diameter large enough to include all of the desired image, would have to be too long to be practicable; in other words, it would remove the body too far from the plate. Dr. G. Bucky, of Berlin, does away with this necessity in a most ingenious way. He reasoned that the smaller the diameter of the cylinder the nearer the object could be approached to the plate, so he constructed a series of small compartments of only 1 or 2 cm. in length with correspondingly small diameters, and walls converging toward the focal centre of the tube. The results are most remarkable. The image on the plate by this method is divided by a grille or net-work of many fine lines, but this can hardly be called a

drawback compared to the increased clearness of the image, and in many cases it may even be deemed an advantage, as it furnishes a scale of measurement that may be very desirable. Its use for dental work is restricted to those cases where a plate of some size is desired, such as for diagnosis of troubles of the antrum or frontal sinus; in these cases it should prove valuable.

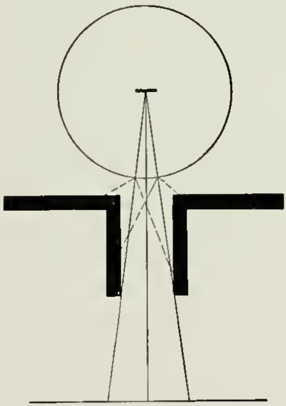


FIG. 76

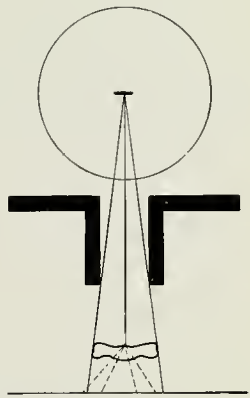


FIG. 77

FIGS. 76 and 77.—Dotted lines indicate secondary rays.

The appearance of the grille on the plate can now, as the writer is informed, be avoided by an improvement upon the first idea, also by Dr. Bucky, consisting of an arrangement by which the whole grille is moved during the exposure so that all parts of the object to be x-rayed will be equally subjected to the penetration of the rays. This lengthens the exposure only by a very short time, but cuts out the secondary rays to the same extent as if stationary. This new apparatus bids fair to attract universal attention after the war.

THE USES OF THE X-RAYS IN DENTISTRY.

Under various headings the uses to which the *x*-rays are put in dentistry are as follows:

A. For purposes of diagnosis.
B. For "checking up" the work of the operator.

A. Diagnosis.—

I. For the detection and location of unerupted or impacted teeth in the practice of orthodontia and in pathological conditions brought about by the same.

For the determination of:

II. The amount of absorption of roots or bone.
III. The destruction of bone as a result of alveolar abscess and granuloma.
IV. The presence of cysts.
V. The destruction of the alveolus in pyorrhea.
VI. The position of broken-off nerve broaches or other instruments, as well as perforations.
VII. Fractures of roots.
VIII. The existence of pulp stones or deposits of bone in the pulp chamber.
IX. Caries of roots under crowns or caps and approximal cavities in teeth which closely approximate.
X. Antrum troubles (roots extending into, or foreign bodies in antrum).
XI. Neuralgia (exostosis and hypertrophy).
XII. Necrosis (sequestra).
XIII. Tumors.
XIV. Fractures of jaws (gunshot lesions).
XV. Foreign bodies in the esophagus, larynx or bronchi, resulting from accidents during dental operations.

B. For "Checking Up" the Work of the Operator.—In the determination of:

I. The length, shape and direction of roots.
(*a*) For crown and bridge-work.
(*b*) For extraction (especially of the lower wisdom teeth).

II. The thoroughness or lack of thoroughness of root canal fillings.
III. For "checking up" the different stages of root canal treatment and
IV. For the same purpose in apiectomy.
V. For determining whether an inlay or other filling projects beneath the gum.

A.

I. In recent years, through the influence of Angle and others, the regulation of the child's teeth is undertaken much earlier than when the old maxim obtained of waiting till all the permanent teeth had erupted. The diagnosis of the position or possible non-existence of teeth in the maxillæ of young subjects is of vital importance to the orthodontist. The *x*-ray is of inestimable value in these cases as a means, and in most cases as the only means, of accurately determining the existing conditions, and it is not an exaggeration to say that without it in many cases treatment would better be postponed until the eruption of the permanent teeth.

In the case of impacted posterior teeth an extra-oral radiograph is often indicated and should there be any doubt as to the relative position of the roots of erupted and those of impacted teeth, a stereoscopic skiagraph is often of great value.

Radiography is also useful in determining the size and length of the roots of teeth to be moved. Should these teeth remain permanently loose after regulating, the operator would certainly be held responsible unless he had taken radiographs before the beginning of the treatment.

In the event of the loosening of teeth with strong and long roots the orthodontist stands a far better chance of exoneration than had this precaution not been taken; whereas if permanent loosening takes place when the roots are small and short, the dentist would in every case be blamed and held responsible for having failed to avail himself of this sure method of determination previous to beginning treatment.

In cases of impacted teeth the determination of the angle of axial deviation from the proper direction, which prevents the eruption, can be very accurately obtained by means of a radiograph. Occasionally more than one view will become necessary, with a different direction of rays. A few cases

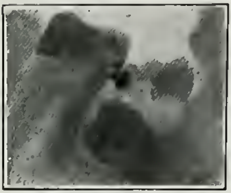


Fig. 78

Fig. 79

have occurred in the writer's practice where the simple separation of the two teeth adjoining a slightly impacted one, has afforded space enough for the latter to erupt easily.

Fig. 78 shows an impacted left lower second bicuspid with deciduous second molar. After extraction of the latter and

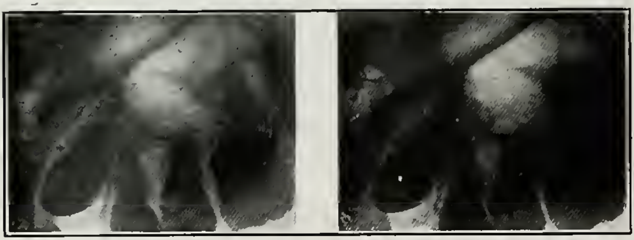


Fig. 80.—Stereograph of right upper canine.

separation of the first molar and first bicuspid the tooth assumed its normal position (Fig. 79). Fig. 80 shows an impacted right upper canine, the position of which appears clearer in the stereograph than in the single film. After widening the arch and separating the lateral incisor and

first bicuspid, the canine should be able to erupt normally. Radiographs taken at various stages during the process of separating the two teeth adjoining the impacted one are very desirable in determining the necessary force to be applied.

Fig. 81.—Impacted canine.

Figs. 81 and 82 show impacted upper canine.

Cases in which the radiograph has shown the hopeless condition of missing incisors and canines are unfortunately not rare.

Fig. 82.—Impacted canine. Taken by J. J. Lowe, Boston.

Fig. 83.—Impacted canine in seemingly otherwise edentulous maxilla. Taken by J. J. Lowe, Boston.

Fig. 84 shows a condition of two missing laterals which relegates the case from the orthodontist to the mechanical dentist.

Impacted teeth are the cause of many pathological conditions by virtue of the abnormal pressure they exert upon the roots of teeth and various nerves and other tissues.

Fig. 84.—A case of missing tooth germs.

Fig. 85

Fig. 86

Figs. 85 and 86.—Impacted lower wisdom teeth. Taken by J. J. Lowe, Boston.

Absorption of the roots of neighboring teeth and caries of the same is no rare occurrence and could not be determined with any certainty by clinical diagnosis alone. The x-ray is an indispensable means of ascertaining the truth in these cases.

In cases of inflammation of the tissues surrounding an impacted lower wisdom tooth which presents a condition simulating ankylosis, and making extraction necessary, the shape and position of the roots of the teeth may become of vital importance, and here again the x-ray is of inestimable value, and no up-to-date dentist would care to undertake such extractions without obtaining a radiograph as a guide in operating.

In cases in which the operator sees a possibility of such a condition in his patient's mouth, it is advisable to have a radiograph taken while the condition still permits of the mouth being opened and the film inserted comparatively easily, which in the case of the lower wisdom teeth is a

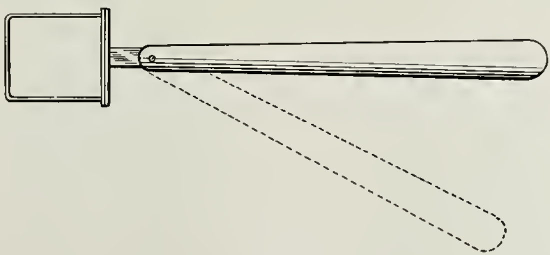


FIG. 87.—Film holder.

proceeding accompanied by considerable discomfort to the patient even under normal conditions. For this reason, and especially in inflamed conditions of the angle of the jaws, Heinz Bauer has constructed a film holder which the writer has found indispensable at such times. The film holder consists of a German-silver case of suitable size, attached to a movable handle. After inserting the film the case is closed by an aluminium shutter which is easily penetrated by the rays, offering hardly more resistance than the paper packing. It can be readily sterilized, and forms a most important part of the dental x-ray operator's outfit.

Tousey speaks of a film holder that is somewhat similar in shape, but the ease with which Bauer's may be adjusted

to fit either side of the mouth seems to the writer a great advantage.

II. Many cases of absorption of the apical part of roots have (before Röntgen's discovery) proved to be one of the greatest disappointments to the dentist. Many hours of treatment, a burden to the dentist and vexation to the patient, might have been spared to both had the operator been able, as he is now, to see if such treatment is hopeless or not. The writer has in mind a case which, instead of requiring six months of ineffectual treatment with the broach would have been completed in one sitting with the forceps had x-rays been available. Even minute degrees of absorption may be the cause of never-healing fistulæ and can easily be recognized on a good, sharp radiograph, and the tooth condemned to extraction or root amputation without further useless treatment.

Fig. 88

Fig. 89

Figs. 88 and 89. Cases of absorption in connection with alveolar abscess.

Fig. 90 shows left upper first and second bicuspids taken six years after amputation of roots. Both teeth firm and surrounding tissues healthy.

Fig. 91. Case of fistula of right upper central incisor, carrying a pivot tooth, and accompanied by extensive loss of bone structure. Amputation of apex was resorted to. Fig. 92 shows end of root lost in abscess cavity during opera-

tion. Fig. 93 shows condition after amputation. Fig. 94. Case a year and a half after operation. The cavity has been almost entirely replaced by newly formed bone.

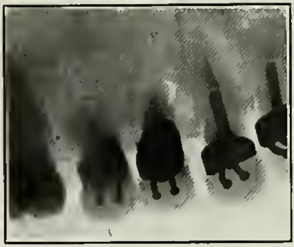


Fig. 90

Fig. 91

Fig. 92

Fig. 93

Fig. 94

Fig. 95

Fig. 95. Left upper first molar four years after amputation of anterior buccal root; tooth firm and is doing good service.

Fig. 96

The radiograph is also of use in cases of pulp exposure in deciduous teeth in which it is desirable to apply arsenic. The degree of absorption of the roots shown on the film will help to decide the operator as to the safety of the procedure.

Fig. 97.—Deciduous lateral with partly absorbed root and missing permanent lateral incisor. Taken by J. J. Lowe, Boston

Fig. 98.—Absorption of roots of lower deciduous molar without underlying permanent tooth. Negative. Taken by J. J. Lowe, Boston.

The old theory that the roots of the deciduous teeth are absorbed, owing to the pressure upon them by the erupting permanent teeth, has been conclusively disproved by radiography. For many x-rays have shown the roots of deciduous teeth to be partly or wholly absorbed without a trace of a

permanent tooth under them to which this absorption could be attributed.

Fig. 96 represents the left upper deciduous second molar with roots nearly wholly absorbed without any trace of a bicuspid above it.

When teeth have been broken off as a result of an accident, the *x*-ray is also a very valuable way to determine the stage of development of the root prior to devitalizing or crowning.

III and IV. The *x*-ray has proved itself to be of inestimable value in the diagnosis of the extent of destruction of bone as a result of alveolar abscess. The part of bone destroyed by the abscess absorbs comparatively little of the rays, so that these darken the corresponding part of the sensitive film to a degree more or less marked, according to the size and depth of the abscess cavity. Writers have recently been differentiating more and more between "alveolar abscesses" and "granulomata" and their appearance on the film in contradistinction to that of some forms of cysts. The differential diagnosis in these cases is not always as simple as it was hitherto considered.

An acute alveolar abscess may not be at all apparent on the film, as in the preliminary stages no bone decalcification has as yet taken place, consequently no radiolucent area will show on the film. Pus may have accumulated under the periosteum or gingiva after having pierced the outer plate of bone, through one or more minute openings, especially in the maxilla, without appreciable destruction of the periapical bone. But not until decalcification has progressed sufficiently and a cavity has finally developed at the apex or side of the root does this change announce itself by a correspondingly radiolucent area.

According to Thoma proliferating periodontitis, caused by poisons and ferments which stimulate new growth, is generally the first stage of alveolar abscess and granuloma, bringing about thickening of the pericemental membrane and consequently the appearance of a radiolucent line surrounding the end of the root. The pressure of this thickened membrane upon the surrounding bone causes its gradual decalcification

and absorption, producing the so-called abscess cavity. The term granuloma should, in the writer's opinion, naturally denote the next stage, that of an effort by nature, albeit pathological, to restore lost substance by the process of granulation inside the thickened membrane.

Dieck has made the distinction between cyst and abscess or granuloma, as they appear on the film, in that he describes the walls of the granuloma as more or less undefined and those of the cyst as sharply outlined. As cysts are now believed often to develop from epithelial granulomata, this distinction seems no longer entirely satisfactory. Besides, conditions of surrounding tissues may obtain which may cause the walls of the cyst to appear less defined.

According to Thomas,[1] if the abscess does not fill with new bone tissue, "a walling off of the abscess cavity and the formation of a sterile cyst about the apex of the root may occur. It may be surrounded by a smooth white border, which demarcates it sharply from the surrounding cancellous bone. This line is somewhat similar to, but less dense than the white border of the antral shadow."

In interpreting radiographs we should try to differentiate between an area of lessened density and a direct cavity, which, covered perhaps by a thin layer of dense bone, may present the same appearance. We should make it clear to ourselves that the radiograph generally presents a sort of composite shadow of superimposed successive layers of healthy soft tissue, normal and diseased bone, products of decomposition, pus, serum and any substance lying between the outer skin and the film or plate, and that only a comparison between the appearance of the area in question and the surrounding structures and adjacent teeth can give us a means of determining the degree and extent of the lesion.

It is always advisable to take more than one radiograph in cases of suspected alveolar abscess, especially in the region of the bicuspids and molars, as owing to overshadowing by other roots, etc. (for example in the case of abscess around apex

[1] J. F. Thomas, Dental Summary, June, 1917, p. 417.

of the palatal root), the radiolucent area, while not being visible on the first film, may show very distinctly if the radiograph is taken from another angle.

A radiolucent area will not necessarily be a proof of an active focal infection, for the treatment may have taken place and nature not yet had time to form new bone tissues in the cavity. The appearance of an area more radiopaque than the surrounding structure will of course point to over-calcification resulting from inflammatory stimulation, as in the healing of fractures. This will show the pathological process to have taken place at a previous date.

The appearance of absorption at the root end as well as exostosis or ankylosis with absorption of the pericementum are indicative of a process of longer standing. These considerations, in connection with the clinical anamnesis of the case, may aid in forming a correct diagnosis.

In determining the presence of granulomata of the upper first bicuspids the direction of the rays should be more from the front than with the second ones, so as to bring out, if possible, the apices of both roots. Many faulty diagnoses have been made by not considering the probable overlapping of the buccal over the palatal root.

For upper molars, the rays should be directed more from above, if it is desired to bring out the palatal root on the film, and more horizontally in order to show the buccal roots.

Lowe advises directing the rays a little from behind in taking first and second upper molars, in order to avoid the shadow of the malar bone.

It is of course advisable to take radiographs from time to time after the treatment of alveolar abscess, by apiectomy or otherwise, in order to determine the degree of calcification that is taking place. These radiographs should of course all be taken under the same conditions of tube resistance and current strength, as well as time of development and strength of developer.

The disconcerting discoveries of recent years, since Hunter first drew the attention of the medical and dental world to the intimate causal relations between oral foci of infection and

numerous systemic diseases of hitherto obscure etiology, have served to bring about the most desirable coöperation of the medical and dental professions. This immense progress could never have been achieved without the help of radiography, and this alone is enough to give the Röntgen rays a high rank in the list of methods of diagnosis.

The history of each case should be carefully studied and considered; a dark shadow does not necessarily mean the presence of an active infected focus, especially in the cases that have been previously treated by competent dentists and when nature has not yet filled up the cavity with new bone tissue.

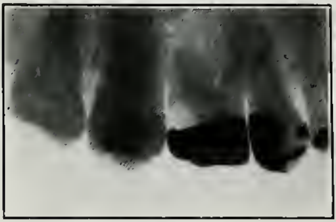


Fig. 99

On the whole every radiolucent area at the end of a root should be regarded as a potential factor of disease and eliminated by treatment, apiectomy or extraction, unless considerations such as mentioned above are proved to exist. The bacteriological examination of such periapical areas in all doubtful cases should constitute a decisive factor in determining the course of treatment.

Fig. 99 is an illustration of both destruction of bone and absorption of the end of the root of the affected molar.

One or more broaches inserted into the nerve canal and extending through the apical foramen of the affected roots will often show the operator through which of them communication with the abscess cavity has been established.

The writer has at times seen cases of marginal abscess on the sides of the roots of teeth with living pulps; these also may be shown on the radiograph.

The variety of cyst in question is generally the radicular, in contradistinction to the follicular; it occurs oftener in the superior than in the inferior maxilla.

FIG. 100.—Abscess on lower molar showing extensive destruction of bone.

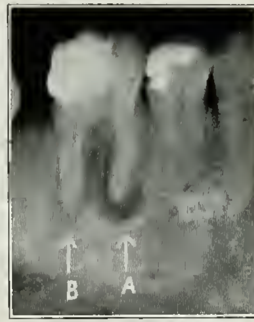


FIG. 101.—Abscess involving two roots of molar. Negative. Taken by J. J. Lowe, Boston.

FIG. 102.—Abscess cavity involving upper canine and first bicuspid.

FIG 103.—Cyst involving upper lateral canine. Taken by J. J. Lowe, Boston.

Radicular cysts are generally of traumatic origin and in many cases the age of the patient at the time of the

accident may be fairly accurately determined by the degree of arrested development of the root and the size of the canal,

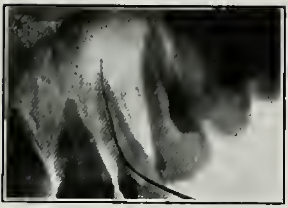


Fig. 104.—Broach inserted into root canal and protruding into abscess cavity.

Fig. 105.—Connection with antrum shown by introduction of broach.

Fig. 106.—A case of fistula opening on the cheek and accompanied by considerable loss of bone.

Fig. 107.—A case of fistula opening on the chin with probe inserted through fistulous opening. Taken by J. J. Lowe, Boston.

if the accident occurred at a time before the root of the tooth in question was fully developed.

Fig. 108.—Dentigerous cyst in mandible containing two biscuspids which were subsequently removed. Radiograph also shows impacted second molar and wisdom tooth occupying a horizontal position.

Fig. 109.—Showing arrested development of root.

The approximate date of lesions of a traumatic nature, resulting in pyorrhea or absorption may be established fairly conclusively by the *x*-rays. Fig. 109 illustrates a case of

arrested development of the right central incisor which shows the flaring of the canal at the apex, causing slight hemorrhage upon insertion of the broach and interfering with the stopping of the canal with gutta-percha. The age of the patient at the time of the accident, according to her statement, was verified by the radiograph.

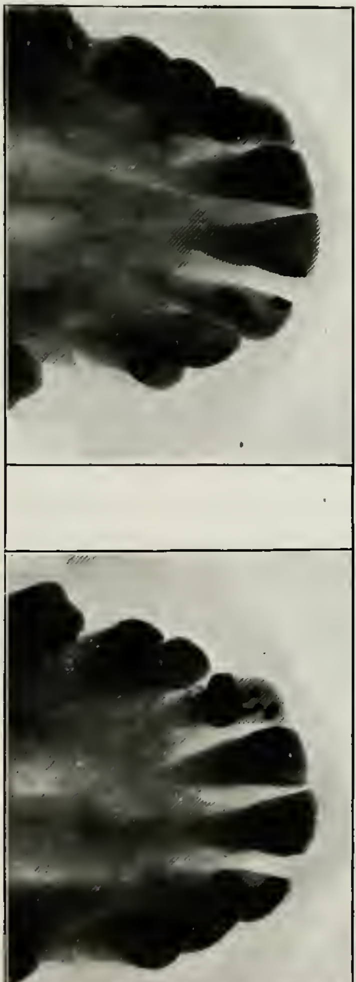
Fig. 110.—Showing extensive destruction of alveolus around lower molar.

Fig. 111.—See page 188.

V. The dentist or prophylactic specialist should not be satisfied to undertake the treatment of any pronounced case of pyorrhea without first determining by x-ray diagnosis the degree of destruction of the alveolus surrounding the teeth in question, and should compare this first radiograph with one or two taken several months or even years after treatment. The presence of calculus on the roots is also in many cases readily discernible on a good x-ray film, but much experience in the selection of the tube and in the time of exposure is necessary to detect this in every case, whereas the amount of absorption is apparent on all but the very poorest films.

The appearance of a slightly radiopaque streak extending through the anterior teeth (especially the lower), and giving rise to the suspicion of a pulp stone, may be caused by a ring of hard calculus extending around the neck of the tooth or lower down on the root. In these cases the unmistakable radiopacity caused by the calculus usually also shows on the approximal surfaces of the teeth in question, thus facilitating diagnosis.

The taking of a stereoradiograph is often of use in determining the extent of destruction of the alveolus (Figs. 112 and 113); moreover, the operator can in some cases more



Figs. 112 and 113.—Destruction of alveolus by pyorrhea. The absorption of bone shows conspicuously if viewed through a stereoscope.

easily distinguish by this process whether calculus has been deposited upon the palatal or labial wall of anterior teeth.

A sharp radiograph will show the presence or absence of the linea dura of the alveolus on the approximal wall of a tooth affected with pyorrhea, and thus enable the operator to judge better of the chances of successful treatment. Of course this does not apply to the lingual or labial wall of the root.

It has been observed that in many instances after treatment of pyorrhea the condition of the teeth and surrounding tissues has, clinically speaking, greatly improved; that is to say, the flow of pus has stopped, the teeth have become firm, the pockets closed up, and the gums tightened around the roots; still the radiograph taken at this time may indicate hardly any restoration of bone. The writer has often remarked this appearance and can only explain it by the fact that prior to the filling up of spaces by new bone structure the toned-up connective tissue and mucous membrane forming the gum substance cling to the pericementum so tightly that the tooth has in reality become vastly firmer, although the actual formation of bone does not take place until much later. This condition, however, does not show on the radiograph, probably because connective tissue and the pus-containing pockets shown on the first film present approximately the same degree of resistance to the *x*-rays.

A radiograph, taken perhaps for an entirely different purpose, occasionally shows a tooth apparently hanging in midair that clinically seems comparatively firm (Fig. 111). There seems, however, every reason to assume that when a pyorrhea case has been skilfully and successfully treated, restoration of bone around the roots and in existing pocket cavities takes place; this depends, however, on the age of the patient and the severity of the case.

VI. The determination as to whether a broken-off instrument in a root canal has or has not perforated the side of the root is not always to be arrived at by taking a single radiograph, as, for instance, the protruding part of a broach perforating the buccal or palatal wall of the root of an upper incisor can probably not be detected as such if the rays are

directed from the front, whereas, if striking the tooth more laterally it may easily become visible. A stereoradiograph is often of value in such cases.

The fact that a radiograph is a composite shadow picture of the various layers penetrated by the rays, should never be lost sight of and unless the protruding portion of the instrument or pivot is seen outside of the margin of the root, the most aggravated case of perforation might appear merely as a comparatively harmless piece of metal lying within the canal. Of course the presence of a fragment of a broach is never an agreeable discovery in a root canal, but when both radiographic and clinical examination show it to be well inside of the roots, the probabilities are in favor of its doing no great harm if entirely incorporated in the canal filling. In upper first bicuspids a perforation between the roots is usually not easy to detect by means of the x-rays.

Fig. 114

Fig. 115. — Broken off broach which has passed through apex of root. Taken by J. J. Lowe, Boston.

Fig. 114 shows a broken-off root-canal drill perforating the side of the root.

VII. Fractures of roots can readily be recognized by radiographs. These should in all cases be taken after any trau-

matic lesion to teeth or jaws, and can often save the surgeon or dentist much time and trouble. One case that occurred in the writer's practice recently serves to illustrate this fact clearly. An officer had received a blow against his front teeth by a vigorous toss of his horse's head. The mesial corner of the left central was broken off and the right one was fractured so that the labial surface was split and hung only by a piece of gum. After its removal the pulp was found to be intact and not exposed, that part of the tooth being apparently as firm as the other teeth. In order to avoid killing the pulp it was decided to make a platinum cap with porcelain facing, and this was set and no inconvenience experienced for the first two weeks. But then the patient returned with a feeling of uneasiness and looseness of the cap, which made an *x*-ray seem desirable. This showed another horizontal fracture about 6 mm. from the apex, which was aggravated by the cap, causing the two parts to become more and more disconnected, and ending in the condition described above. Now, the root upon which the cap was cemented seemed perfectly normal, but had an *x*-ray been taken at once, both patient and operator would have been spared much trouble and annoyance, for the root would have been extracted at the beginning. The film, though plainly revealing the condition described above, unfortunately did not show strong enough contrasts to be reproduced here.

VIII. The existence of pulp stones may be demonstrated by the Röntgen rays, showing as a body of approximately the same density as the dentine, and occupying a part of the otherwise dark-appearing pulp chamber. These pulp stones are by no means always apparent and it requires much experience and technic in choosing a tube of proper vacuum and timing the exposure correctly to obtain satisfactory results. G. M. Brown advises using a rather softer tube for this purpose. The radiopacity of a pulp stone will usually be greatest at its centre, gradually diminishing toward the periphery. One circumstance should not be overlooked, and that is the possible presence of buccal stoppings of deceptive size, as they are liable to dampen the operator's joy on

considering himself the happy possessor of a genuine pulp stone *x*-ray, a thing of comparatively rare occurrence in the practice of the general dental practioner who limits his *x*-ray work to his own practice.

IX. One of the most discouraging sights, and one that unfortunately occurs in the best of practices, is that of caries under crowns and caps or fillings that extend under the gum. In cases of suspected approximal cavities in very crowded teeth where no fillings have yet been inserted, and which could hitherto be detected only by wedging, the writer has repeatedly been able to detect caries by taking a radiograph of two or more of the teeth in question.

Fig. 116

Fig. 117

Fig. 118

Figs. 116, 117 and 118.—Caries under caps and old stoppings.

Before setting any gold inlay extending well under the gum, an *x*-ray, with inlay held in place, should always be taken and will save much trouble in smoothing away "catches" subsequently.

X. In affections of the antrum the *x*-rays often form an important link in the chain of diagnostic factors, and a radiograph should certainly be taken if there remains any doubt after illuminating the oral cavity and resorting to the usual means of diagnosis. The radiograph should be taken with a large plate postero-anteriorly, the face of the patient firmly pressed against it, and the exposure should be shortened by the use of a good intensifier. The tube should have a resistance of 10 to 12 Wehnelt or 7 to 8 Bauer qualimeter.

Empyema of the antrum will be indicated by a lighter appearance of the affected side, as the rays will be absorbed more readily by the pus-containing secretions. There are, however, so many cases in which the density of normal bone may

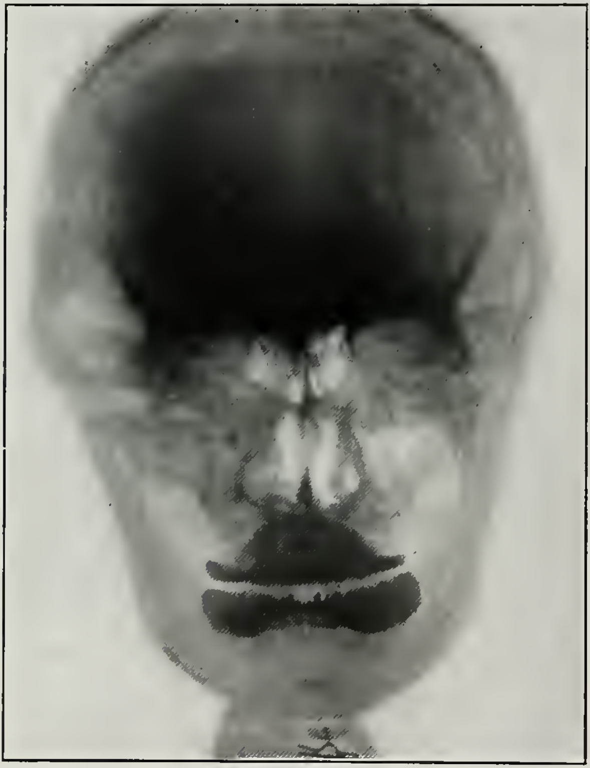


Fig. 119

vary considerably on either side, that the radiograph alone should not be considered sufficient. Fig. 119 shows a case of empyema of the right antrum and frontal sinus. The affected antrum appears darker on the print owing to the absorption

of the rays by the pus-containing fluids. On the primary plate, of course, the appearance is reversed. The patient had not removed her artificial dentures.

A skiagraph may also be taken with a large plate or film in the mouth held between the teeth, the rays being directed from above, but the presence of the bicuspids and molars is likely to preclude a clear image of the parts in question. Should the upper jaw, however, be edentulous, or at any rate so far as molars and bicuspids are concerned, the radiograph taken in this manner and showing at least a part of the antrum of each side, may be a very valuable help to diagnosis. The presence of roots, dentigerous cysts, or even foreign bodies in the antrum may of course be easily demonstrated in this way. Dieck reports a case in which a bicuspid root was forced up into the antrum during an extraction. In this connection it will be well to bear in mind the possibility of misinterpretation referred to before, which may be brought about by the inclusion of the root-ends on the film within the image of the antrum, while the root itself may occupy its normal position in the maxilla.

In determining whether a root actually or only apparently extends into the floor of the antrum three possibilities should be considered:

(*a*) Whether the root is situated buccally or palatally of the antrum.

(*b*) Whether there is actual perforation of the floor of the antrum.

(*c*) Whether the root, while extending into the antrum, is still covered by convolutions of alveolus, periosteum and pericementum.

In this case a thin radiopaque line, representing the fold of alveolus, next to this a fine radiolucent line, the periodontal membrane, should be visible. Only a sharp radiograph will show this.

A sure means of verifying a radiographic diagnosis of empyema of the antrum, and one which the writer has not often seen mentioned in connection with the transillumination of the oral cavity with the electric mouth lamp, is the pupil

test. The diagnostician should ask the patient to look at him, and then in another direction, repeatedly, while the mouth lamp is illuminating the oral cavity (of course in a darkened room). The lips should enclose the tube containing the bulb. If both pupils appear luminous, like a cat's eyes in the dark, there is conclusive proof of the non-existence of empyema. Should, however, only one pupil be visible it would strongly point to empyema of the opposite side, as the transparency of the pupil over the affected antrum would be impaired by the presence of pus. In some cases especially in men, the bone structure is so dense that the pupils would not be visible even under normal conditions, but with a strong mouth lamp they will generally show through a healthy antrum. The writer has found this a most reliable test.

Fig. 120

XI. The subject of facial neuralgia is one that extends into so many different territories that its thorough consideration is of course out of the question here. Suffice it to say that its origin is often of so obscure a nature, while the trouble itself may become a source of intense agony to the patient, that no possible aid to its diagnosis should be neglected, and an x-ray may reveal conditions (chiefly of impacted teeth) the removal of which may restore health and comfort to the sufferer. Fig. 120 shows an impacted left lower second bicuspid pressing against the first molar root and causing absorption and all the symptoms of severe neuralgia. The patient has experienced no more trouble since the extraction of the molar. Upson, among others, strongly urges the radiographic examination of the jaws and

teeth of all patients suffering from mental disorders, even if no direct indication of their dental origin is apparent.[1] Exostosis of roots is also one of the causes of neuralgia which, before the era of the Röntgen rays, were a source of the greatest difficulty to the diagnostician, often leading to the extraction of one tooth after another until the exostosed

Fig. 121

Fig. 122.—Taken by Dr. H. F. Hamilton, of Boston, Mass., shows a marked degree of condensing osteitis or hypercementosis. The pericemental membrane has been almost entirely obliterated and the teeth appear ankylosed. Patient is suffering from neuritis in one arm. According to Price, condensing osteitis of the roots is often coexistant with general arthritis.

ones were revealed and removed, whereas now an x-ray easily shows us the seat of the trouble. Osseous deposits on the wall of the pulp chamber causing pressure on the pulp are also often detected by the Röntgen film. Fig. 121 shows exostosis on roots of both bicuspids (also an ill-fitting cap on the first molar).

[1] Dental Cosmos, May, 1910, p. 525; May, 1912, p. 954,

XII. Necrosis and osteomyelitis in their different stages afford the *x*-ray an opportunity of proving its value as a diagnostic factor. At first, according to Pfahler, a transparent condition of the bone is apparent, owing to the disturbance of the fine net-work of cancellous structure, caused by the destruction of bony elements. The sequestrum, which on the film appears light, surrounded by a dark area of decalcified bone, is usually easily recognized and its location and removal is thus facilitated.

The appearance of necrotic and osteomyelitic portions of bone on the radiograph may prove confusing to the average dentist and such conditions should in the writer's opinion, not be diagnosed by the *x*-ray alone. As alveolar abscess is a simple form of osteomyelitis, the appearance of the latter on the radiograph in its first stages is identical with that of the attacked portion of bone in ordinary alveolar abscess. From this, its simplest form, osteomyelitis shows destruction of greater portions of bone interspersed with denser areas due to sporadic inflammatory stimulation of bone growth. There may be sequestra surrounded by newly forming bone. Periosteal proliferation may also cause thickening of the cortical layer of the bone.

XIII. For the diagnosis of tumors the Röntgen rays have been used in many instances with success, and although the dentist would naturally not be very conversant with the differential diagnosis of these dangerous diseases, the appearance of a certain transparency of the bone on the photographic film may serve to arouse his suspicions and determine him to call in a pathologist or surgeon while there is still a possibility of successful operation. Pfahler says:[1] "Tumors of the lower maxilla are shown by a disturbance in the cancellous tissue, at first consisting merely of an absorption of the calcium salts, resulting in a greater transparency, then followed by more complete destruction. This disease is not definitely outlined as in necrosis, fading gradually into healthy bone, and is often associated with the formation of new tissue.

[1] Dental Cosmos, September, 1911, p. 1084.

Carcinoma seems to cause more destruction of bone and less new tissue than sarcoma. Most of the primary tumors seem to be sarcoma, but the metastatic are most likely to be carcinoma. Not only the character but the extent of the disease may thus be determined, and thus material assistance secured in outlining treatment." In differentiating between exostosis and malignant bony growths, Shenton[1] emphasizes the regularity and uniformity of the former in contrast to the ragged and spotty appearance of the latter.

As regards the differential diagnosis of cysts and some forms of malignant tumor (according to Thomas[2]), almost the entire jaw may be absorbed, in the case of the former, except for a thin cortical shell. "The diameter of the bone may be markedly increased without the continuity of the shell being broken, unless by trauma."

In the case of malignant tumors "there is a tendency to break through the cortex and involve the soft tissues at a relatively early stage."

XIV. Fractures of the jaws also offer a field of usefulness for the radiograph which should be welcomed by the dental surgeon. Prior to the adoption of any treatment, an *x*-ray should be taken to indicate the proper course to be pursued; whether a splint or wire ligature should be applied and in the latter case where the bone is strong enough to be perforated so as to introduce the wire. According to Pfahler, fractures of the jaws are liable to occur at the places weakened by an extensive abscess cavity which again affords the liability of infection to the fractured area. The radiograph shows at first a dark, irregular line on the film, followed in later exposures by its gradual disappearance through the formation of normal bone. Non-union is of course also apparent on the film, and is indicated by the persistance of the dark area and formation of sequestra.

In cases of fracture of the jaws, especially those caused by gunshots, stereoscopic radiographs are of great value in helping the surgeon to obtain a clear image of the line and

[1] Disease in Bone and its Detection by the X-rays, 1911, pp. 64, 68.
[2] Dental Summary, June, 1917, p. 417.

depth of the fracture and the position of the fragments and sequestra. The plates can be beautifully viewed in the various stereoscopes on the market. Many instruments and methods for localizing bullets, fragments of shell or other foreign bodies have been devised that have proved very valuable in this war, some in connection with radiostereography, others with double radiography.

XV. When one considers the number of cases in which the dentist, especially one occupying himself largely with crown and bridge-work, may experience the pang of suddenly seeing a band or post disappearing down the throat of his patient, one can only wonder at the comparatively few instances recorded. But if it be only once in a lifetime, it is enough to make the dentist thankful for possessing an x-ray outfit, if for no other purpose than to be able to locate the object so as to facilitate its removal before it is too late. A surgeon with the necessary instruments should be summoned so as to be at hand when the plate has been developed.

B.

I. The value of determining the length, shape and direction of roots for crown and bridge-work is so self-evident that it requires no further remark, except to refer the reader to Dieck's and Ottolengui's methods of measurement with a broach, which have been already described.

Fig. 123 shows the correct direction of the drill in preparing the root for a temporary pivot tooth, while in Fig. 124 it is not difficult to see the advantage an x-ray would have afforded if taken while fitting the post of the crown.

II and III. The determination of the degree of perfection attained in root-canal filling is another field for the x-ray and one which does not always afford an unalloyed pleasure to the operator, no matter how conscientious he may be in his work, for what dentist has not had the experience of occasionally having failed to fill a canal to the apex, which without the detective x-ray would have satisfied his conscience entirely? It will certainly help to show up the operator "who always succeeds

in filling every root canal to the very apex, no matter how small or crooked it is." On the other hand, the x-ray has that comforting feature in that it shows that an innumerable

Fig. 123.—Diagnosis of direction of canal.

Fig. 124.—Result of not diagnosing by x-ray.

quantity of roots treated by conscientious and skilful men have not been filled to the apices, but are, so far as we can judge, doing as well as if this ideal had been possible of attainment. This is not meant as a plea for careless root-canal filling, but to show that where manual skill fails to accomplish

Fig. 125

Fig. 126

Figs. 125 and 126.—Result of not checking up while drilling out root canal for post. Taken by J. J. Lowe, Boston.

the impossible, Nature often takes care of things herself. The writer certainly considers it more advisable to treat minute remnants of nerve filaments in roots found by the

radiograph to be cured, as a more or less negligible quantity, after having sterilized them as well as possible, than to run the risk of drilling through the side with a Gates-Glidden or Beutelrock root-canal drill unless other indications point to apiectomy or extraction. The fact that gutta-percha as a root-canal filling is most desirable has also been proved, it would seem conclusively, by the *x*-ray, for the writer has in several cases seen how kindly nature takes to it even when it has been pushed through the apex, as appears in Fig. 127. In this case the root filling of the canine that has been inserted six or seven years previously, was not the cause of the taking of the radiograph, the gutta-percha not having caused the slightest inconvenience. Rhein, indeed, in filling root canals makes a special point of "encapsulating" the periapical area of the root with gutta-percha.

Fig. 127.—Gutta-percha extending through apex.

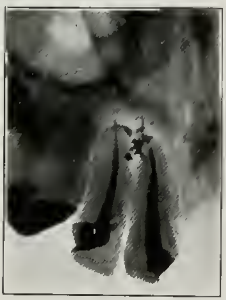


Fig. 128.—Gutta-percha extending through apex. Taken by J. J. Lowe, Boston.

Fig. 129 shows extensive absorption of the end of left upper canine root. The protruding part of the gutta-percha root canal stopping has evidently assumed a nearly horizontal position.

The objection to paraffin as a root-canal filling on account of the inability to distinguish it on the radiograph has been met by the addition of bismuth which makes it show on the film, although perhaps not quite as distinctly as gutta-percha,

and for this reason it is recommended for the purpose by Prinz on account of its non-irritating qualities. Indeed the tissues take most kindly to it.

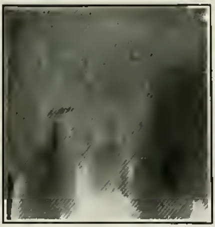


Fig. 129.—Absorption of root and gutta-percha protruding.

The conclusions often arrived at upon examination of radiographs taken to determine whether or not a canal has been filled perfectly, are not always correct, for a perfectly filled canal may present the appearance of an imperfectly filled one, if the rays are directed a little too much from above or below, as the case may be. Either the labial or lingual side of the apex may protrude, on the film, beyond the end of the filling so as to mislead the observer, as the following diagram will illustrate.

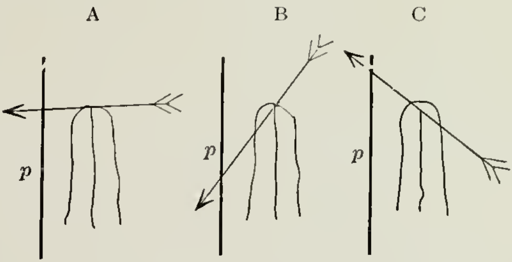


Fig. 130.—*p*, plate. Arrow shows direction of rays.

This is one more reason for taking more than one radiograph from different angles, or stereoradiographs, in case of the least doubt.

DEVELOPMENT OF RADIOGRAPHS.

One of the very important factors in obtaining a good radiograph is its development, and much could be written on this subject.

In the first place an absolutely light-proof dark-room, however small, is a necessity, except in the case of those who use a light-proof muff and developing tank. The writer considers that the advantage of developing in complete darkness, as is the case with the muff, are offset by the disadvantage of being unable to observe the process of development by red light in the dark-room, and even if the rapid films may suffer to some small extent from red light, the operator can shield the tray, so as to make this a negligible quantity.

The conditions under which all exposures are made in dental radiography cannot, theoretically at least, be always the same, so as to justify a uniform time of development. Nevertheless good work is being done with these muffs, for if one film upon examination is found to be under-developed while the other remains covered up, the development of the latter can be prolonged.

Illumination of the developing pan by a mild red light from beneath, as used by Lowe, is pleasant to the eyes of the operator. By covering the pan with a tight-fitting cover the process of development of one film may be prolonged while its duplicate is examined in the fixer by ordinary electric light, and the best one chosen.

A developer which ensures excellent results is the Eastman x-ray developer. It is sold in the form of powders with full directions for use. The Eastman Kodak acid fixing powder is to be recommended as a very reliable fixer.

The time usually recommended for developing is about five minutes, or until the image begins to turn gray, as in ordinary photography.

PART II.

ELECTRO-THERAPEUTICS.

CHAPTER VIII.

ELECTRO-PHYSIOLOGICAL EFFECTS.

General Considerations—Conduction by Ions.

General Considerations.—Research of a purely physiological nature has demonstrated the existence of electrical manifestations in animals. Differences of potential of the surface of the body are always present and may be detected by delicate electrometric methods. Electrical manifestations are especially noticeable in some species of fish, greatest of all in the electric eel and the torpedo, which yield electrical discharges of considerable magnitude. Electric current is especially noticeable in muscle and nerve tissue, but it has been stated that it is to be found in all tissues of the body. This phenomenon has been tested with delicate galvanometers especially constructed for the purpose, and non-polarized electrodes. The skin has been stated to possess a current after it has been removed from the body (as for grafting), by placing a non-polarizing electrode on the inner side and a delicate galvanometer in circuit with another electrode on the outer side, as long as vitality exists a weak current will pass from the greater potential on the inner side to the outer. The healthy skin has also been shown to possess currents which can be excited and will flow toward

the portion which is negative to the greater potential. Exertion of the brain and contraction of muscle produce currents which can be detected by the use of electrometric instruments.

The electrical currents which occur in muscles and nerves are of a continuous kind when in repose, and intermittent when in activity. Physiological experiments have been performed on fresh living muscle and nerves which demonstrate this phenomenon, but it has been stated that the continuous electric current flows as an effect of artificial condition produced by removal of the tissues from the body. The intermittent current can be produced by stimulating the tissue, when a current will flow at each contraction.

Conduction by Ions.—In the living body when a continuous current is applied it is conducted by the tissues of the body from one point of contact to the other as if the conduction were through a liquid, the body, being an electrolyte, the current is conveyed by charges which are imparted to the ions contained in the tissues. Lewis Jones[1] describes this process as follows: "Conduction in watery solutions of salts (and the tissues of the body may be regarded as coming into this category) take place only by the conveyance or transport of charged particles or 'ions' through the liquid from one metallic terminal to the other, and without this movement of material particles there is no conduction in liquid solutions. The moving particles or ions are the result of the dissociation of the molecules of the salts by the process of solution, so that a solution of sodium chloride in water contains abundance of dissociated ions of chloride carrying negative charges and of sodium carrying positive. When a current is applied there is a double movement among the ions—a procession of the chlorine ions to the positive pole and of the sodium ions to the negative, every ion carrying its appropriate positive or negative charge, so that the measurement of the current by a galvanometer in the circuit gives an accurate indication of the number or amount

[1] Medical Electricity, p. 300.

of the chlorine ions brought to the positive pole and of the sodium ions brought to the negative."

This transfer of the current by charging of the ions in both directions constitutes an important factor in the ionic effect of the current; that electro-positive ions move in their particular direction while at the same time electro-negative ions move in the opposite direction should not be lost sight of.

When metallic electrodes are applied to the surface of the body, a migration of ions occurs at both poles from the surface of the electrode (metallic ions enter from the positive pole) for this reason at the site of contact of the electrode, where ions are often not desired, great caution should be exercised to prevent the entry of deleterious ions from the metal or liquid electrode into the body at that point. Electrodes should be covered with some protecting material like chamois skin or lint which should be kept scrupulously clean; if the metal be brought in contact with the skin, destruction of the tissue might occur by the transfer of ions either from the metal or from salts in the tissues at the point of contact; this will be manifest by a blister or destruction of the tissues, a caustic effect, similar to that produced by plunging a metallic electrode into tissue for destruction of hair follicles and usually referred to as electrolysis. Leduc in referring to this effect of the passing of the current between electrodes applied to the tissues of the body says: "The electrodes employed for medical application of electric current are either insensitive electrodes—carbon, platinum, etc.—or sensitive electrodes—zinc, copper, etc.—or electrolytic electrodes formed of aqueous solutions of salts, acids, or bases. In the case of the insensitive electrode, the anions, after having given up their charges at contact with the anode, become anhydrides, which, in order to make the corresponding acids, carry off hydrogen from the tissues which they destroy—$2Cl + H_2O = 2HCl + O$—and oxygen is liberated.

"The kations, after contact with the kathode, take the chemical character of the alkali metals, and carry off the

hydroxyl group from the tissue, which they destroy, freeing hydrogen: $K + H_2O = KOH + H$. If we employ electrodes which can be acted on by the products of electrolysis, the phenomena at the anode consists, firstly, of the formation of acid, with the destruction of the tissue, and then the attack and dissolution of the electrode by the acid formed. From this there results a salt of the metal of the electrode which gives rise to the phenomena presented by the electrolytic electrodes. When we use as electrodes electrolytes —*i. e.*, solutions of salts, acids or bases—there is produced by the passing of the current an exchange of ions between the body and the electrodes. At the anode the body gives up its anions and receives the kations of the electrode; at the kathode the body gives up its kations and receives the anions of the electrode."

These effects produced in the body by the passing of the current are identical with the electrolytic effects produced in a cell or other electrolyte as already described. Ions may be invisible, their presence only being detected by their effect on the tissues of the body or by a secondary chemical combination by which they are transformed into a new product which can be seen. The movement of ions from the surface of metallic electrodes in an electrolyte, the rapidity with which they are transported, and their direction of penetration was demonstrated by the author in an experiment before the Odontological Section of the Royal Society of Medicine (vol. v, pp. 102), 1912. Metal electrodes of the same area and cross-section as those used by him in actual practice for the treatment of pyorrhea alveolaris were used for the experiment, which was performed as an ocular demonstration of the small amount of current strength required to instantaneously produce a movement of ions from soluble electrodes. To quote the experiment from the proceedings of the Royal Society of Medicine, vol. v, 1912:

"I have here two glass tubes, each 6 cm. long and 1 cm. in diameter, open at both ends, these tubes are filled with coagulated albumin. In one tube the albumin had been

mixed with a trace of ferricyanide of potassium, the other contains pure albumin. The tubes are placed side by side standing on the small platform, which has a platinum electrode connected by wire to the thumb-screw, to which is attached the negative lead wire; the other ends are in contact with a similar electrode which is connected with the other thumb-screw, to which is attached the positive lead wire. The albumin is the electrolyte, which, being white, readily shows the movement of ions as they take place. Two lengths of iron wire, each 2 cm. long and 1 mm.

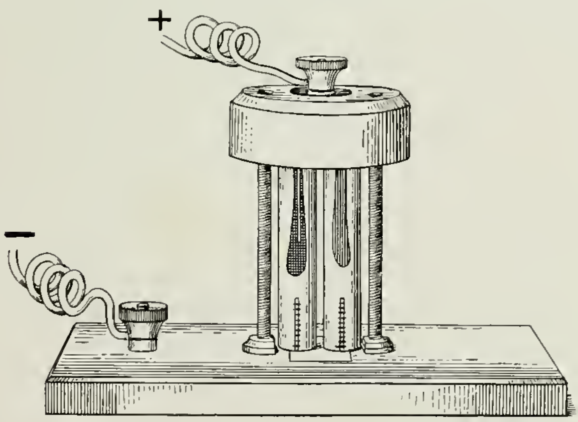


FIG. 131.—Ferrous and copper ions in albumin.

thick, are placed one on each end of the glass tube containing the mixture of albumin and ferricyanide of potassium, passing along the side of the glass so that they are readily seen, the ends of the wire are bent over the sides of the glass and are in contact with the platinum electrodes. A similar arrangement is carried out with copper wire in the other glass tube which contains pure albumin.

The reason for mixing ferricyanide of potassium with the albumin in the tube in which is placed the iron wire is that ferrous ions are invisible, but when brought in con-

tact with ferricyanide of potassium, Prussian blue is formed. Iron and copper are both soluble electrodes, and when a current of about 5 ma. is passed you can see ferrous ions and copper ions migrate from the surface of the metals, the ferrous ions staining the albumin a Prussian blue and the copper ions a light green; this takes place at the positive pole. At the negative pole no change takes place except the formation of hydrogen gas. I would draw your attention particularly to the rapidity with which the ions are formed and the depth of penetration."

The effect produced by the passing of the current through this electrolyte demonstrates some of the changes which actually take place in ionic medication. Much more conclusive experiments have been carried out by Dr. N. S. Finzi,[1] of London, with a view of determining the path which ions take when introduced into the living tissues. The experiments were performed on cats, rabbits, a monkey, and a dog. A number of various ions were introduced into the tissues of the animals by ionic medication, the tissues containing the ions were removed, and the ions stained *in situ* by saturating the tissues with a chemical which caused a colored compound with the ions. The results of these experiments are of great practical importance in showing conclusively the great depth of penetration of some ions. To quote one of these experiments as published in the *British Medical Journal:*

"A monkey was anesthetized by chloroform and a pad soaked in potassium ferricyanide was placed over the front of its knee, the area which the solution touched being limited by a window cut in a piece of oil-silk. This pad was connected with the negative pole, that attached to the positive pole being placed on the back. A current of 10 milliampères was passed for thirty minutes, and then the animal was killed. Before its death, however, the knee was removed by cutting through the thigh and the leg, and was placed in a solution of ferrous sulphate. A control

[1] British Medical Journal, November 2, 1912.

experiment was performed in which a pad of potassium ferricyanide was fixed on a monkey's knee for the same length of time, no current being passed, and the knee was subsequently treated in the same way. The next day the knee was opened, and it was found in the case in which the current was used that the skin, subcutaneous tissues, and patellar tendon over which the window had been placed were stainêd an intense blue from the interaction of the ferricyanide ions and the ferrous sulphate, and further that this blue extended right into the joint, there being a stained patch on the cartilage which penetrated right down to the bone. In the control the blue did not even penetrate the skin. This definitely proves that it is possible to introduce the ions of some substances directly into a joint, even into the cartilages; at any rate of a comparatively superficial joint like the knee."

This experiment is one of many performed by Dr. Finzi which was quite as convincing and is quoted to show that penetration of ions takes place equally well at the *kathode* as at the anode if the acid radicle type is applied with the intention of driving in that particular ion.

The following experiment, which the author performed on gum, periodontal tissue and alveolus, provides definite proof that ions penetrate a considerable depth into these tissues with a very low current strength. A dog was anesthetized and an electrode of the size which is usually used for treating periodontal membrane, was wrapped with a little cotton-wool and moistened with a solution of 3 per cent. ferrous sulphate. This was connected with the positive pole of a generator, and pressed into the gingival trough and periodontal tissue to a depth of 4 mm. and a current of 5 ma. passed for three minutes. This was repeated at several points about the roots of teeth in the maxilla and mandible. The animal was killed by the anesthetic, and sections of the gum and bone about the treated portions removed. A portion of the gum of corresponding size and position, which was not treated, was also removed for comparative examination. All the sections were thoroughly washed and placed in a 10 per cent. solution of

potassium ferricyanide for twelve hours. The ferrous ions (which are colorless) were by this treatment colored a Prussian blue, and were seen to have penetrated the whole thickness of gum tissue to the epithelial layer on the outer surface, and also passed into the bony structure to a depth of about 15 mm. The ionized gum tissue was cut into sections and mounted for examination under the microscope. Sections were also prepared of the untreated tissue.

The microscope revealed the fact that the ions had penetrated the tissues from the periodontal membrane to the epithelial layer on the outer surface.

These sections were submitted to Mr. Hopewell-Smith for examination and he agreed that the ionization of the tissues was complete and clearly shown.

This definitely proves that ions penetrate freely into gum, periodontal membrane and alveolus with a current of 5 ma. in three minutes.

Leduc demonstrated the penetration of ions into the body by using colored ions. He points out that if a solution of permanganate of potash be employed on both arms and current passed, the ions stain the tissue at the negative electrode, a brown punctate rash appearing at that pole, while at the positive pole no such staining takes place. The effect on the system he demonstrated by employing sulphate of strychnine with a positive electrode applied to the inner surface of the ear of a rabbit. If no current be passed the strychnine solution can stay indefinitely in position without any effect, but by passing a current tetanic convulsions typical of strychnine poisoning causes the death of the rabbit.

The author once saw a patient suffer from alarming toxic effects of cocaine under the following circumstances: The patient, a powerful man, had an incisor fractured and the pulp exposed; in order to anesthetize the pulp a pellet of cotton-wool soaked in a 20 per cent. solution of cocaine was placed on it and a platinum electrode applied to this conveying positive electricity, the negative electrode was held in the hand. The current strength had risen to

Fig. 132.—Photomicrograph of untreated tissue.

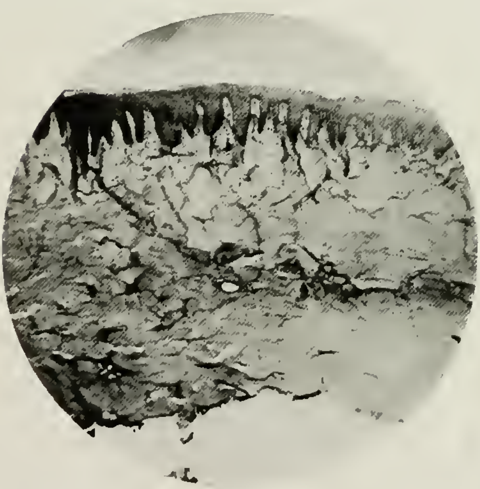


Fig. 133.—Ionized tissue, showing a marked contrast.

0.5 ma. in about three minutes, when the patient, who had hardly perceived the current, began to show symptoms of cocaine poisoning. The application was removed at once, but he rapidly got worse, the heart action became feeble, and the patient prostrate, the effect lasted for two hours. It is likely that the cocaine ions were transmitted into the system not only through the pulp but also through the lacerated periodontal membrane, but it is not likely that more than $\frac{1}{16}$ grain of cocaine was on the application, of which not one-half had been formed into cocaine ions. There was no likelihood of the drug being swallowed, as it was easily controlled in that position in the mouth.

CHAPTER IX.

PHYSIOLOGICAL EFFECTS OF CURRENTS.

Cataphoric Effect — Electrolytic Effect — Path of the Current in the Body—Motor, Sensory and Special Nerve Effects—Effects of Current on Nutrition—Effects of Current on Salivary Glands—Resistance Effects of Current Passing through the Body.

Cataphoric Effect.—The phenomenon of cataphoresis is dependent on the laws governing osmosis and the osmotic effect of a continuous electric current on certain liquids and compounds by which they are conducted *en masse* through a porous septum in the direction of flow of the current; that is, from the positive to the negative. It is based on the discoveries and experiments of many eminent workers in electrotherapeutics. Porret, in 1815, explained this tendency of fluids to be transported in the direction of flow of current, and later the investigations of Becquerel, Munk, Galitien, Wisse, W. J. Morton, and others have added light on the subject. Most modern works on electrotherapeutics contain some explanation of the cataphoric effect of the current, but medical writers, as a rule, pay little attention to it, and seem to be sceptical of the reality of the cataphoric effect when applied to the body. They seem to be unable to separate it from other effects which take place at the same time when a current is passed through the body, and far more attention is being given at the present time to other electrolytic effects of the current. That this phenomenon takes place there can be no doubt, but to what extent it is applicable in electrotherapeutics from a dental aspect will be described in another part, at present the theory of cataphoresis will be dealt with.

"Osmotic pressure[1] is that force which determines the movements and the rate of exchange between solutions in immediate contact or separated by membranes, more or less permeable. Substances in solution move from more concentrated regions toward regions less concentrated, while the fluid moves in the opposite direction. This movement constitutes the phenomenon of diffusion, and osmotic pressure is the motive force which animates matter in this way and produces diffusion."

The rate of osmotic diffusion is influenced by conditions of temperature, relative degree of density, chemical action, and relative concentration of the separated fluids in the same circumstances as regards kind of separating medium and quantity of fluid employed in the experiment. Slightly higher temperature will raise the osmotic pressure; greater densities are slower in osmotic effect than weaker solutions; fluids of acid reaction are more rapid than alkalies. Osmosis of liquids of different concentrations follow the same laws which govern osmosis of gases in the spaces which contain them.

An electric current passed through solutions separated by porous membrane, will greatly facilitate osmotic pressure in the direction of flow of current.

This fact may be demonstrated by the experiment of placing two fluids of different densities in a U-shaped glass tube which is divided in the middle by a porous membrane which admits of ordinary osmotic effects. If the two halves contain the same amount of fluid, but one side a solution of sodium chloride and the other pure water, osmotic pressure will cause a tendency for the levelling up of the strengths of the solutions by the moving of the weaker solution through the membrane to the stronger; but if an electric current is passed through the liquid in circuit from the *salt* solution to the water it will be found that osmosis is greatly increased by the action of the current, and that the liquid on the positive side will be forced through the separating membrane

[1] Leduc.

into the negative side, increasing the bulk of liquid on that side at the expense of the other, and conveying molecules of sodium chloride with it. This is brought about by electrical diffusion or cataphoric diffusion, and is a simple illustration of the tendency of liquids to be conveyed *en masse* in the direction of flow of current. In addition to this, however, a formation of gases takes place at each electrode, oxygen at the positive and hydrogen at the negative.

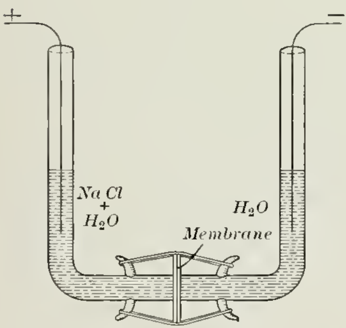


Fig. 134.—U-shaped tube before a current is passed.

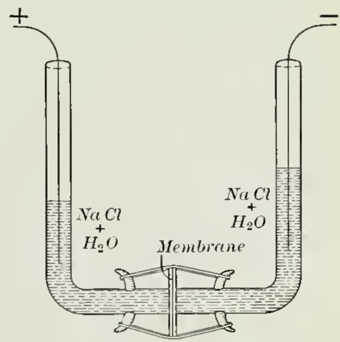


Fig. 135.—Effect of current on solution in tube.

This movement of the molecules of liquid in the direction of flow of current coincides to some extent with Faraday's law of electrolysis, which says that electricity flows *with* matter *through* it.

W. J. Morton[1] has detailed a number of physical experiments to prove the osmotic effect of the current, and demonstrated by them that by the action of the current fluids move *en masse* in an electrolyte from the + to the − electrode.

The author has tried many of these experiments and in every instance has obtained the result described, although he does not deduce the same conclusion from the phenomena in every case.

[1] Cataphoresis, p. 91.

Repeating Dr. Morton's experiments it will be found that if a + electrode be placed in one side of a ball of moist clay and a − electrode in the opposite side and a current passed, drops of moisture collect about the − electrode; this is a physical transfer of water in the direction of flow of current.

If a + electrode be placed in a piece of raw meat with a − electrode some distance away, a similar transfer of moisture from the tissues will take plaee to the − electrode, and the tissue will contract about the + electrode and adhere to it in consequence of the coagulation of albumin about the surface of the electrode.

The author has done similar experiments with eoagulated albumin, using platinum electrodes; drops of water exude about the − eleetrode and the album'n contracts and adheres firmly to the + electrode.

These effects may be purely eataphoric, but some other experiments quoted by Dr. Morton hardly eome under the cataphoric effect; for example, if two copper electrodes be plaeed in eoagulated albumin, at the + electrode a green stain will be produced; at the − electrode drops of water but no green eoloring. This green stain should not be attributed to eataphoresis, it is an ionic effect eaused by the dissociation of copper ions from the surface of the soluble copper electrode whieh migrate in the direction of the − element; the transfer of liquid to the site of the − electrode is brought about by eataphoresis, so that the two phenomena occur simultaneously. Take a hard-boiled egg and cut it lengthwise and remove the yolk, place the white in a saueer containing a solution of iodine and fill the hollow of the section of egg with weak starch water, connect the iodine solution with a *negative* electrode and the stareh with a *positive* electrode. On passing a eurrent the iodine will pass through the albumen and give the iodine test with starch. This can hardly be demonstrated as a cataphoric effect because the reaction takes place against the direction of flow of current, but this is one of the experiments which W. J. Morton uses to amplify cataphoresis; it is, in fact, a good example of the migration of iodine ions

from the negative pole. Quoting further from W. J. Morton, "Cataphoresis is essentially a property of currents. The fact that the transporting power of the current diminishes and finally ceases, in direct ratio to the diminution of resistance, indicates to me that in liquids we have to deal with what I have called a 'movable' resistance in contradistinction to what in solids (metals, etc.), might be termed 'stationary' resistances. From this point of view a fluid is projected or moved along in bulk simply because it does offer resistance." This opinion would seem to indicate that currents of considerable magnitude are required for this transfer of liquids *en masse* when cataphoresis is carried out in living tissue.

Some authors have pointed out that the transport of liquids or compounds appears to take place from the negative toward the positive, in which case it is termed *anaphoresis*,[1] to indicate the action at the cathode, but this phenomenon coincides with the ionic effect and it is probable that in every such instance in which substances are supposed to produce this anaphoric effect, the phenomenon is due to the migration of ions and in no way a transfer of the substance *en masse* as in cataphoresis.

In medical electro-therapeutics very little importance appears to be attached to the cataphoretic effect, because such large currents are required for this to be appreciable, the electrolytic effect which is produced by the passing of a galvanic current through the body is regarded as the means of applying drugs in the ionic form rather than by cataphoresis, and while both phenomena undoubtedly occur in some instances, it is ionic medication which is the principal effect obtained from the electrical energy. Lewis Jones[2] says: "A movement of the electrolyte comparable to osmosis takes place under the influence of the current, and generally occurs in the direction of flow of the current, namely, from the positive to the negative poles; fluids can in this way be made to pass through membranes or porous diaphragms

[1] Guilleminot: Electricity in Medicine, p. 212.
[2] Medical Electricity, p. 304.

against the force of gravity. It has been proposed to make use of this process for the introduction of drugs into the body through the skin, but the migration of the ions referred to is a more important factor in the percutaneous introduction of drugs by means of electric current."

Cataphoresis has been largely used in practice by the dental profession, principally for producing anesthetic effect on sensitive dentine, pulps of teeth, and periodontal membrane with cocaine. In 1888 Dr. McGraw, of California, read a paper on the anesthetic effect of cocaine in solution with alcohol on sensitive dentine, this was among the first of the early writings on the dental aspect of the phenomenon, and many practitioners have since recorded the same effect with the galvanic current.

W. J. Morton attributes all the effects of the current on solutions used for medication with a galvanic current to cataphoresis with the exception of the effect of the product of soluble electrodes such as copper, iron, zinc, etc., which he designates as "electric diffusion;" this is what is known now as ions of the metals which are dissociated by the action of the current, of this he points out with accuracy that "Another noticeable feature of electric diffusion of salts formed from soluble electrodes is that a remarkably low current strength suffices to set free a large amount of the metallic salts." On this point depends largely the great usefulness of soluble electrodes in furnishing antiseptic salts in the form of ions.

The practice of anesthesia of sensitive dentine by the application of cocaine in guaiacol with the electric current has occupied the attention of a large section of the dental profession in America and elsewhere. This effect has always been attributed to cataphoresis, and with the teaching of such an authority as Dr. W. J. Morton no one doubted that this is the real effect, but the author has investigated this subject and after a number of years of experience with the current has adopted the view that the effect obtained when a continuous current is used on oral tissue is not a cataphoric effect, especially in the use of cocaine for the obtunding of sensitive dentine. A number of experi-

ments and also the practical application of the current, not only for the treatment of the hard tissues of the teeth, but more especially for the treatment of mucoperiodontal tissue, in which, working on the cataphoresis theory, were often negative in results, forced on him the conclusion that the current strength which it is possible to use on the tissues of the mouth is quite inadequate to produce the cataphoric effect; that the good results obtained were from ions with an exceedingly low current strength.

When working with the expectation of obtaining cataphoric effects, a low current strength only being possible on such sensitive tissues as periodontal membrane or dentine, mixtures of drugs were employed which were not driven into the tissues *en masse* for the lack of sufficient current strength, but the effect of the current on these mixed drugs was to set in motion ions of their component parts. Results obtained in these circumstances were, to say the least, unreliable, but good results were invariably obtained with simple salts from which ions of an antiseptic nature were readily conducted into the tissues. An exhaustive test of this method has led him to the conviction that cataphoresis, as stated above, is never the effect. Ionic medication is always the only effect which is produced in the tissues of the oral cavity, when an electric current is used for medication.

It is quite conceivable that a substance like cocaine when acted upon by water is split up into ions and in this state is readily introduced by the electric current into the microscopic organic tissue of dentine. It is quite an easy matter to anesthetize the dentine and the pulp of a sound tooth by drilling a small hole through the enamel just *to* the dentine, and by applying $\frac{1}{30}$ gr. of cocaine dissolved in water with a current strength of 1 ma. for five to eight minutes. The author has frequently done this to incisors to facilitate the operation of splinting loosened pyorrhea teeth. The transfer of the anesthetic in these cases is undoubtedly an ionic effect, molecules of water containing cocaine cannot be transferred *en masse* with so small a current. On the other

hand, the author has shown by physical experiment that ions migrate immediately with a current strength of 0.5 ma.

The ion is an inconceivably small particle when we consider that it is only a fraction of a molecule. It can be readily transferred into a conducting channel of microscopic dimensions such as the tubuli of dentine with comparative ease, and that it does travel with the current has already been shown in the chapter on ions (p. 46), where it was shown that ions are the conveyors of electrical charges, that they move with the current and are the means of conducting it, not only in the direction of flow but in the opposite direction.

Electrolytic Effect.—The electric current passing through the body has the property of decomposing it at the sites of contact of the conducting media. Metallic electrodes in contact with tissues produce acid and oxygen at the anode and alkali and hydrogen at the kathode, by the decomposition of the salts and fluids of the body, these are the primary effects; a complex reaction also takes place dependent on the kind of metal employed and the composition of the tissues; for example, if sodium sulphate ($NaSO_4$) is the salt present at the kathode, the positively charged ion Na becomes neutralized at this pole and combines with water in the tissues to form caustic soda (NaOH) and hydrogen; a secondary reaction takes place, the NaOH contains a positive ion Na and a negative ion OH, the OH is an ion which moves with great rapidity and also has a caustic action, it is repelled from the kathode and may have a destructive reaction on the tissues. This caustic effect is sometimes produced in the hand and other parts of the body; the hydroxyl ion (OH) by its caustic action destroys the skin and a small vesicle is formed.

The electrolytic effect of the current is utilized in medical practice for producing coagulation of blood in aneurysm, at the anode a firm small clot is formed and an acid reaction produced, at the kathode a more diffused alkaline clot.

The complex structure of an electrolyte like the body is productive of numerous electrolytic effects dependent on the kind and position of the electrode, but the acid and

oxygen at the anode and the alkali and hydrogen at the kathode are constant effects. In practice the electrolytic effects on soluble electrodes, notably zinc and copper, are of inestimable value for their antiseptic effects on the tissues.

When a metallic electrode is placed in tissue, as, for example, a thin copper probe in an alveolar fistulous tract, after the current has passed for a while the electrode will adhere firmly to the tissues if the current is of positive sign; if the poles are now reversed the tissues at once release their contraction about the electrode and it is easily removed.

Path of the Current in the Body.—When a current is passed through any part of the body, it is not conducted from one electrode to the other in a direct course, but branches out in curves and at right angles to the points of contact, the lines of current are denser at these points and radiate from them (see Density, p. 72). Lewis Jones, in describing diffusion of current in the body, says, "The path of a current between two electrodes placed upon the body surface is not to be marked out simply by drawing direct lines from one to the other, for the whole of the conducting tissues between the electrodes helps to provide a passage for the current, which spreads out from beneath the positive electrode, becoming less and less dense as it occupies a wider and wider sectional area of the conductor, and again grows denser as its lines of passage once more gather together to reach the negative electrode." According to this description of the lines of current a positive electrode applied to periodontal membrane in the incisor region would show divergence of direction something after the lines of the diagram. With a small spear-shaped electrode, such as indicated on the diagram, the density of current is greatest at the very end, and radiations of current take place in all directions from the surface of the electrode, which is brought in contact with the moistened tissues. Electrodes of such small area and cross-section, intensify the density as already stated (see p. 73); for this reason a very small current strength produces an effect on the tissues equal to that

produced by a very much greater current strength applied with electrodes of large area, but, of course, only acts on a much smaller surface. A continuous current passing into the tissues from an electrode which measures 2 sq. mm. concentrates the flow of current from its surface to an extent which makes it possible to medicate the tissues more perfectly (in a tissue of such small resistance to current as periodontal tissue) with a current strength of only 2 ma. than would a flat electrode of 2000 sq. mm. (applied to the surface of a high resisting tissue like the skin) with a current strength of, say, 20 ma. So, also, if a large flat electrode be applied to the surface of the gums the density of the current is reduced and the penetration of medicines applied in this manner will be very slight with a small current strength.

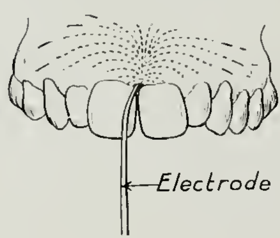


Fig. 136.—Lines of current diffusion about a positive electrode placed in periodontal tissue.

The diffusion of current in the body and effects of density are of great practical value in dental electrical treatment; the concentration of current from small electrodes permits of perfect means of medicating diseased periodontal tissue with a current strength which is readily tolerated by such sensitive tissues, at the same time the electrolytic effect produced at the positive pole is usually non-productive of caustic effects; the effect of density is therefore a great aid, rather than detrimental in this method of using the current.

Motor, Sensory and Special Nerve Effects.—When a continuous current is passed through the living body it has the effect of stimulating the motor, sensory, or special nerves

nearest to the point of contact of the active electrode. When a current is applied to a motor nerve it causes contraction of the muscle which that nerve supplies; in the case of a sensory nerve it conveys to the brain impressions of sensations (weak or strong) according to the strength of the stimulation; if the nerve trunk is an ordinary mixed nerve it conveys both; in the case of nerves of special sense the stimulation causes a response to the particular sense which the nerve ordinarily controls.

The stimulation of motor nerves occurs at the closure of the current if the current be at least about 1 milliampère, and at both make and break of the circuit if the current is a strong one. This will depend on the position of the nerve stimulated; the superficial nerves will respond to a direct stimulation with a very small current strength, while a deep-seated nerve trunk will require a larger current to effect a stimulation and contraction of the muscle it supplies. Stimulation of motor nerves only occurs at make or break of current and is a spasmodic single contraction, which does not continue (except the current be a very large one) even though it continues to flow.

If the current is a rapidly interrupted one, as from an induction coil, the stimuli to the nerve are so rapid that the contractions become tetanic, there is not time between make and break of the current to permit of relaxation or reconstruction, so the muscles supplied by the stimulated nerve contract tetanically. This effect of stimulation of the nerve supply to certain muscles is much resorted to in medical practice for practical testing of certain muscles from certain points called motor points, from which muscles are stimulated to produce contraction effects for diagnosis of disease, its bearing has little to do with dental treatment.

Certain forms of discharges from high-frequency machines will also produce motor stimuli.

The stimulation of sensory nerves is influenced to a great extent by the strength of the current and the density at the point of stimulation; the nature of the ions which are introduced at the point of contact of electrodes vary the

sensation; with some the penetration at the kathode produces more pain than at the anode, but generally the reverse is the case. The sensory stimulation of mucous tissue is productive of a feeling of pricking of a vast number of fine needles; on periodontal tissue, of a burning sensation. These sensations are increased or diminished with the area and cross-section of the electrode. If a small continuous current is passed with a very small electrode the sensation is one of tingling, burning at the point of contact, an impression which would be wholly lost with a larger electrode conveying the same amount of current. Interrupted currents produce sensations of shock, the severity of which will depend on the electro-motive force; if the interruptions are exceedingly rapid the sensation produced is a benumbed effect, that is, a true anesthetic effect which has been utilized occasionally for the operation of extraction of teeth "without pain," a principle which has been much questioned in some quarters as to its true efficiency, but which no doubt is a real anesthetic effect, by which sensation of pain is benumbed.

A continuous current of 10 to 12 ma. passed with a small anode into the periodontal tissues in the molar region of the superior maxilla will sometimes cause what the patient describes as dizziness, but in fact is a general anesthesia effect; how far this can be carried it is difficult to say. The writer has a patient on whom he has, on several occasions, noticed this general anesthetic effect when a small zinc electrode is placed in a pyorrhea pocket between the second and third upper molars and a current of 10 ma. applied for about five minutes; for the first minute or so slight tingling pain is the effect of the stimulus, but soon the parts become numb and when the current is raised to 10 ma. for a short time, the patient behaves as if passing under the effects of a general anesthetic, but is easily roused on removal of the current, and described the feeling as that of dizziness; the senses of hearing and sight are also dulled, but respiration is not affected.

The stimulation of nerves of special sense gives rise to effects peculiar to the sense which is dependent on the

particular nerve. Stimulation of the olfactory nerve gives rise to a sense of smell, the auditory nerve to the intensifying of sound, the optic nerve gives rise to sensation of flashes of light. The stimulation of the optic nerve through the filaments of nerves connecting it with the nerves of the teeth is the best example of stimulation of nerves of special sense. A continuous current applied to any of the teeth in either the maxilla or mandible, with a current strength of 1 ma. or more passing through dentine or cementum of live teeth, at make and at break of current, the stimulus will cause a flash of light in the eye which receives the stimulus; this flash is very vivid and resembles lightning. It has long been known that current applied to the vicinity of the eye, as on the closed eyelid, causes stimulation of the retina, which produces effects of different colored lights, some say dependent on the pole which is used. With stimulation through the dental nerves the flash is always a bright white light, and is produced by either anode or kathode at the make or break of circuit.

Stimulation of nerves of taste produces a metallic taste. This is noticed by patients taking galvanic baths when the bath comes above the shoulders.

Effects of Current on Nutrition.—Experiments on animals have shown that treatment with constantly varying currents have the effect of increasing their weight; a comparative test in which some young dogs of one litter were treated and others not, all being fed and kept under identically the same conditions, those which were treated by general faradization improved in physical condition and gained tissue weight over those which were not treated. Similar experiments have been carried out with chickens in which it has been found that they improve in size and weight at a rapid rate, owing to stimulation by current. Rhythmical, interrupted, and sinusoidal currents are said to have the best effect on general nutrition, while continuous currents or static electricity is less effective. The benefits derived from general electrical treatment are recognized by the medical profession, and many forms of treatment are employed for general stimula-

tion of the body to secure improvement in certain morbid conditions.

Effects of Current on Salivary Glands.—Continuous currents of small strength applied in the vicinity of nerve supply to salivary glands cause increased secretion by stimulating the nerves controlling the blood supply and increasing functional activity of the glands; copious supply of saliva will be excited in the sublingual glands by applying an electrode to the soft tissue in the region of the lower incisors, cuspids, and bicupids; the submaxillary glands are excited by application of current to the region of the lower molars, and the parotid glands are excited by application to the bicuspid or molar region of the superior maxilla. Generally speaking, electric stimulus to the nerve supply of secreting glands of the body increases secretory activity of the cells and causes an increase of their secretions.

Resistance Effects of Current Passing through the Body.—The resistance of the body is a very complex problem; unlike a metallic conductor, the tissues vary in conductivity according to the kind to which electrodes are applied, and even in the same kind it varies from day to day. The skin offers the most resistance to the passing of current, and this varies according to whether it be moist or comparatively dry (perfectly dry skin is a bad conductor).

Nerve, blood, and muscle are in that order the best conductors of current. Guilleminot says: "The blood plays an important role in the conductivity of the body. Like the other fluids of the body, it is composed of a solution of salts, acids, and bases, and of non-electrolytes, albumins, sugars, and fats."

If an electrode is placed in a mucous tissue the resistance is much less than if the epidermis is the site of contact. This has been explained by Leduc by the idea of migration of ions, the skin being poor in ions, the interchange of ions from the skin to the electrode or from the electrode to the skin is imperfect and resistance to passing of current is increased; but if the parts are saturated with a saline solution which is rich in ions, the contact becomes more complete by

the passing of ions and resistance is reduced. If the anode is applied to periodontal membrane with the hand as contact for the negative element, the resistance of the body is often found to become less as the application goes on, up to a point, especially if the hand electrode is kept well moistened or if a carbon electrode placed in saline solution is used and the whole hand immersed in the solution.

Different methods have been devised for measuring the resistance of the body such as the Wheatstone Bridge, Mergier's ohmmeter, etc. These are generally constructed on the principle of a known E. M. F. and current strength from which may be calculated the resistance according to Ohm's law, but for all practical purposes, if it is required, to ascertain the resistance of a patient in circuit, it is easy to calculate it according to Ohm's law if the electro-motive force at the electrodes on the patient's body is known and the milliampèremeter indicates the current strength which is passing.

Say, for instance, a battery or current switchboard which is equipped with a reliable voltmeter showing the E. M. F in volts, indicates that 4 volts is producing a current strength of 2 milliampères in treating a patient in circuit, the resistance of the patient is calculated

$$\frac{E}{C} = R \quad \frac{4 \text{ volts}}{0.002 \text{ ampère}} = 2000 \text{ ohms.}$$

The distance the electrodes are placed apart also affects the resistance. Some operators in treating periodontal membrane have advocated the placing of the indifferent electrode near the site of ionization, on the neck or under the chin, in which case the resistance will be found to be much less than if the electrode is as far away as the hand.

But the measurement of resistance is not an essential factor in the use of the current therapeutically, except in respect to amount of discomfort which might be caused. It is, however, an interesting point in the constant use of the current to note the variation of resistance in different patients and in the same patient at different times.

Observations of the author led him to conclude that temperament or disposition of a patient has an effect on the resistance of the body; calm, phlegmatic, non-excitable people appear to conduct current better than the nervous, excitable, or irritable. The general health of the body appears also to have an influence on resistance; those in perfect health appear to be better conductors of current, and resistance is increased in those suffering from toxic effect of oral sepsis. The resistance of the body from the mouth to the hand varies considerably and is dependent on a number of conditions, but generally under conditions which may be considered almost identical, measuring it when an active electrode of small diameter is placed in the mucoperiodontal tissue and the indifferent electrode is moistened and held in the hand, the range may be anything between 1300 and 3500 ohms. Resistance is very much increased if tooth structure is included, *i. e.*, the active electrode placed in contact with the dentine and the indifferent electrode held in the hand, and it is further increased if the tooth is dead; the enamel of tooth structure resists the passing of current completely if no moisture is present to conduct over its surface.

The measurement of resistance of dentine through the body is dependent on such a number of circumstances that it is almost impossible to formulate any accurate law which may be said to govern all cases. Opinions vary so widely on this point that it is well that accuracy in this particular has little bearing on the therapeutic effects of the current in its uses for dental purposes. Allowances must be made, in measuring resistance, for variety in density of the tissue, distance between the poles, condition of the skin at contact of the indifferent electrode, conductivity of the body in different individuals, in health, or in certain diseases.

Professor G. Weiss[1] places resistance of the body from hand to hand, in the cases of 16 men measured, at an average of 1300 ohms, and in 7 women at 1500 ohms.

[1] Arch. d'Electricite Médicale, 1893.

Dawson Turner[1] gives resistance from hand to hand at 1375 ohms.

Lewis Jones[2] gives resistance as ranging between 1000 ohms and 2000 ohms "under conditions of medical practice and using salt water to moisten the skin."

The average of 150 cases recorded by the writer from the periodontal tissue of the mouth to the hand holding a moistened electrode was 3250 ohms, but it must be noted that here the one electrode tried was of a very small area.

This estimate was arrived at by recording the E. M. F. from the reading of a voltmeter attached to the terminal of a main current switchboard, and the current strength indicated by a milliampèremeter, the patient being in circuit holding a metallic electrode covered with moistened lint. The average was 13 volts and 4 ma.

$$R = \frac{13 \text{ volts}}{0.004 \text{ ampère}} = 3250 \text{ ohms.}$$

Similar measurements through dentine from tooth to hand gave a varied resistance corresponding with the thickness of the dentine and whether the teeth were alive or dead; one record from the surface of an erosion at the neck of a live tooth was 5000 ohms, another from a slight approximal cavity in a superior central incisor was 7500 ohms; a dead superior premolar with open apical foramen was 4000 ohms. The highest recorded estimate of resistance in live dentine was 10,000 ohms, and this might be due to the very small area of the dentine and size of the electrode. It is evident that resistance of dentine is a variable quantity, and it is difficult to give a definite estimate of what it is as a rule. Some authors have placed it very much higher than these estimates here given.

Dr. Louis Jack[3] states that "resistance of the body including the dental tissues varies from 10,000 to 70,000 ohms," and the same writer, in quoting Dr. W. A. Price, states that author's estimate of resistance "from cavity

[1] Practical Medical Electricity, p. 188.
[2] Medical Electricity, p. 302.
[3] Kirk's Text-book of Operative Dentistry, p. 160.

to the hand" is about 25,000 ohms. It is not stated how these measurements were obtained, but if the estimates of other eminent medical electro-therapeutic authors quoted are correct in their calculation of resistance of the body from one distant part to another, *e. g.*, from hand to hand (taken, for example, the highest given that of 2000 ohms), there is a difference of 8000 to 68,000 in these greatest estimates to be attributed to resistance of dentine. In the latter case no ordinary 18-cell battery producing E. M. F. of 24 volts could furnish sufficient current to overcome so great a resistance, consequently no current would pass. According to Ohm's law,

$$R = \frac{24 \text{ volts}}{0.0005 \text{ ampère}} = 48{,}000 \text{ ohms.}$$

that is, if 24 volts are required to pass a current of 0.5 ma. through the dentine of a tooth, the resistance would be 48,000 ohms, which is considerably under the estimate of 70,000 ohms.

The writer has not found it necessary to use more than 20 volts to pass a current of 2 ma. through the dentine of a live tooth from a small drill hole just through the enamel, with the body included in circuit to the hand. If this calculation is correct, the resistance from tooth to hand through dentine in the case of 20 volts with known ampèrage of 2 ma. is

$$R = \frac{20 \text{ volts}}{2 \text{ ma.}} = 10{,}000 \text{ ohms.}$$

In dead teeth the resistance offered to current will depend somewhat on whether the canal is open at the apex and if there is organic matter or liquid contained to act as a conductor of current. If the apex is sealed with a non-conductor like gutta-percha the resistance will be much increased, as conduction will then have to be through the dentine and cementum, but with an open apical foramen and a liquid solution contained in the canal into which an electrode can be passed, conduction of current by this channel is comparatively easy, and resistance is not as great as it is in the case of a layer of dentine.

CHAPTER X.

ELECTRO-THERAPEUTIC EFFECTS.

Ionic Medication—From a Dental Aspect—The Zinc Ion—The Copper Ion—The Iodine Ion—The Silver Ion—The Cocaine Ion—The Adrenalin Ion—The Salicylic Ion—Advantages of Ionic Medication—Effects of Ions on Bacteria.

The Therapeutic Effects of electrical currents have engaged the attention of the medical profession to a great extent, especially of late. The use of the current is not confined to local treatment only, but general treatment of the whole body for all kinds of morbid conditions; static and high-frequency currents are now considered of great importance. Stimulating, sedative, and ionic are among the medical therapeutic effects of different currents. In surgery the continuous current is largely used for cautery, light, and electrolytic effects.

In Dentistry the subject of electro-therapeutics appears to have been sadly neglected in the past; keen interest was aroused some thirty years ago in America when W. J. Morton, of New York, published his work on *Cataphoresis* in which many valuable suggestions were made on electrical treatment in dentistry. Unfortunately Morton was incorrect in many of his deductions and the development of dental electro-therapeutics on those lines was practically impossible. In his book *Cataphoresis* Dr. Morton made the valuable suggestion that tubuli of dentine can be penetrated by drugs applied with the electric current, and in the case of septic root canals the driving of antiseptic drugs into the structure of the tooth and the sterilizing of the same is far more scientific and effective than the ordinary method of placing antiseptics in the canals. He asserts that "if cataphoresis is employed as a diffusing agent success will be more swift

and sure. There is, in addition to all this, the possibility of carrying medicaments into the periodontal membranes for the treatment of acute infectious inflammatory conditions of that tissue."[1] These valuable suggestions have not been acted upon by the vast majority of practitioners because, in the first place technic was lacking, and, secondly, the subject of electro-physics as it pertains to therapeutics was insufficiently explained to ensure success in the application of the current for the treatment of dental disorders.

In the light of the present-day knowledge of electro-therapeutics, the theory of cataphoresis in dental application must give way to the ionic medication, and then the greatest stumbling-block to the success of electrical treatment of the teeth and other oral structures will be removed. By the lessons taught by research of Leduc, Lewis Jones, d'Arsonval, Turner and others, a more comprehensive view of the effects of the different currents on the body is placed at our disposal. The electrolytic effects on certain salts of an antiseptic nature whereby ions are transported into the tissues (and this with a very low current strength) opens up a field of usefulness to the dental profession of inestimable value. The natural susceptibility of the oral cavity to septic infection constitutes three-fourths of the difficulties placed in the way of almost every operation the dentist is called upon to perform, the burning question ever being how to prevent or to cure sepsis. If, then, an improvement on the ordinary method is placed at our disposal by the use of electric currents, it should be our duty to adopt it.

Ionic Medication.—The theory of the formation and migration of ions and the physiological effect of ions have been detailed in other parts of this work, the therapeutic considerations, bring us to the more practical aspect of this electrolytic phenomena. Certain principles peculiar to the formation and movement of ions in the tissues must not be lost sight of in order to get the best results from this

[1] W. J. Morton: Cataphoresis, p. 238.

method of treatment; all substances are not dissociated by the effect of the current; ether, alcohol, chloroform, and oils are some of these; it therefore would be useless to attempt ionization with these; the dissociation is effected in solutions, and only substances which contain ions in solution can be "ionized:" water is the only solvent which gives any amount of ions, though some are formed in some other liquids. Then, again, it is necessary to know which ions are electro-positive and which electro-negative, that is, which are driven into the tissues from the anode and which from the kathode. Reference has been made to this effect already, and it is not hard to remember that metals, alkalies, hydrogen, and alkaloids are repelled from the positive pole; and acid radicles, iodine, bromine, etc., are repelled from the negative pole; the caustic effect at the negative pole (kathode) should not be forgotten, if by mistake the negative non-oxidizable metallic electrode be applied to the tissues of the mouth with sufficient current, formation of caustic soda, or, more important still, the formation of hydroxyl in the tissues might cause destruction of a tissue which it is desired to stimulate or treat with ions.

Again, the action of the current on some drugs which are escharotic or have a caustic effect on tissues without a current, are completely changed when converted into ions. Iodine and chlorine are examples of this, as are also some strong acids.

The local effect of ionic medication is dependent on the ion used. Nothing but experience can teach the effect of the different ions, the subject is comparatively new; nevertheless, there is now a vast amount of literature detailing the action of ions of different kinds, and it is most noteworthy that medical experience goes to show that treatment of mucous tissues with ions gives the surest results: this is of course not to be wondered at, as it is readily perceived that the conduction of electrically charged atoms or groups of atoms must be facilitated by a soft, moist, good conducting electrolyte, such as mucous or periodontal tissue; whereas the skin, being a poor conductor, sometimes poor in ions

itself, as pointed out by Leduc, penetration of ions from medicine applied to it is not so rapid and not so sure.

To gather from the experience of the medical profession we will do well to examine the reports from one of the very best sources. From this many useful hints may be obtained, which may lead to more extensive use of ions in dentistry. At a meeting of the British Medical Association held in Liverpool in July, 1912, Dr. Lewis Jones[1] read a paper in which he tabulates his own experience and that of the profession in general, with zinc, salicylic, chlorine, iodine, and radium ions; he referred to reports made in the medical journals of Great Britain and on the Continent of successful treatment of a great number of cases of local affections. Under the heading of the zinc ion successes have been reported in treatment of:

Simple chronic ulceration of the leg.
Bed-sore ulcerations.
Rectal ulcerations.
Anal fissure.
Ulceration of the mouth.
Pyorrhea alveolaris.
Ulceration of the nose.
Fistulas.
Gynecological conditions.
Sycosis, furuncle, acne.
Lupus.
Rodent ulcer, etc.

Numerous cures are recorded of all these conditions by the local application of zinc ions. Dr. Lewis Jones chronicles three cases of chronic sores of the nasal cavities cured quickly under zinc ions. He says: "Two of these simulated lupus, but were probably staphylococcic rather than tuberculous. The third was an ulcer just within the nose in a middle-aged lady; it had persisted for several months, and healed at once after a single treatment." He recalls the report of a fistula in the lower jaw as follows: "Marquis and Pappon[2] have

[1] British Medical Journal, August 31, 1912.
[2] Arch. d'elect. méd., 1910, p. 568.

reported three successful cases of fistula in connection with the lower jaw. The applications were of 20 milliampères of one hour's duration, and were repeated every seven days. From four to six applications were made, and in each case the zinc ionization brought to a close a troublesome condition which had lasted for two years or more."

These are but a few of the very large number of cases reported of the healing effect of zinc ions.

Under the heading of "The Salicylic Ion" he has collected a number of reports of cases of:

1. Perineuritis and neuralgia.
2. Painful affections of muscular and fibrous tissues.
3. Arthritis.

In addition to his own vast experience in the use of this ion for the successful treatment of this painful class of disorders, refers to the reports made by such authorities as Leduc, Desplates, Verney, Norin, Circca Salse and Dawson Turner.

In 1913 Lewis Jones published his book *Ionic Medication*, a concise treatise on this method of treatment, in which many clinical results of a convincing nature are recorded and many practical suggestions are made which are singularly adaptable to dental electro-therapeutics. I cannot too highly recommend this work to those who practise ionic medication.

From a Dental Aspect.—Very little has been recorded, so far, of the treatment of dental diseases by ions. Probably the first mention in this country is that by the author (in discussing a paper on vaccine therapy by Dr. Eyre and Mr. Lewyn Payne before the Royal Society of Medicine)[1] in which he said: "For a long time by a method of ionic medication of the periodontal membrane by electric current, he believed he had been producing very similar results in the system to those claimed by the advocates of vaccine treatment. Ions of antiseptic salts were driven into the very protoplasm of the affected tissues and killed the organisms in the tissues, and he took it that the dead organisms

[1] Proceedings of the Royal Society of Medicine (Odontological Section), vol. iii, p. 63.

were absorbed into the blood stream and had an effect upon the opsonins similar to that of vaccine prepared from cultures."

Later in a paper read before the Royal Society of Medicine (Odontological Section), 1912, p. 104, the writer made the following statement: "It has been conclusively shown by many workers in electro-therapeutics that ions of zinc, copper, silver, and iodine have strong antiseptic properties; the principal advantage they possess over ordinary methods of applying them in treatment is that with their electrical charges passing through an electrolyte like the body the ions penetrate the cells of the tissues and (probably on account of a certain amount of coagulation of albumin) are not readily affected by absorption into the general circulation in the same way as drugs which are hypodermically injected; the only question is the depth to which penetration takes place; this seems to me to depend on the amount of current strength which is possible and the kind of tissue which is under treatment; periodontal membrane, for example, will permit of greater penetration than the epidermis.

In medical electro-therapeutics ions of zinc are successfully used in the treatment of such affections as rodent ulcer, lupus, pus-yielding sinuses, etc. In dental practice there are many difficult problems yet unsolved; the most difficult of these is the one in which ionization, to my mind, is a step in advance of the other methods placed at our disposal."

The application of a number of different ions used in the treatment of several dental disorders was also recorded at that time.

For a number of years the writer used the continuous electric current for the treatment of pyorrhea alveolaris, with the idea that cataphoresis was the effect obtained, the principle of mixing drugs of an antiseptic nature with the expectation of driving them into the affected tissues *en masse* has since proved itself to him to be erroneous, a certain amount of success was undoubtedly recorded, but failure was frequent, and in the light of present knowledge

of the electrolytic effect where a current is passed, the writer is convinced that the good effects obtained, resulted from the migration of ions when solutions were used in which ions of metals were contained, and failure was the result of either neutralization of ionic effect by chemical reunion of ions of different kinds, thereby destroying their therapeutic effect (which is a doubtful hypothesis) or the migration of useless ions.

In ionic medication it is advisable to dissociate a particular ion and depend on the therapeutic value of that ion for the effect that is desired. For instance, if the zinc ion is required, a 3 per cent. solution of zinc chloride with a current strength of 2 or 3 milliampères, the zinc ion will dissociate from the chlorine ion at the anode, the former migrating into the tissues. So, also, if a copper ion is desired, a 2 per cent. solution of sulphate of copper will furnish the ion at the anode. But if these solutions of salts are incorporated with non-conducting and non-dissociating solutions like alcohol or glycerin with the expectation of passing them into the tissues *en masse* by cataphoric methods, the current strength necessary for this will exceed the toleration by the patient.

The therapeutic effects of ions on the oral tissue are to my mind of such importance that it should take the place of the present method of treatment of nearly every form of septic infection of the periodontal membrane. The effect is that of sterilizing a septic area by the penetration of the ions into the tissue and the destruction there of micro-organisms. A great variety of different species of bacteria is found, not only in the pockets, but in the tissues forming the boundaries of the pyorrhea pockets, their action on the tissue is to destroy it, the pus being the product of inflammation caused by the presence of bacteria. The destruction of the organisms is the main object of all who treat alveolar suppuration. This is effectively done by passing an electrode into the affected pockets and by the electrolytic effect of the current driving ions of some antiseptic salt into the tissues. The depth of penetration of these ions will depend

on the current strength which is available. The ions are deposited in the tissues, they penetrate the protoplasm of the cells and radiate in all directions. The effect is a local sterilization of an area of infection which cannot be reached in any other way. The practice of syringing, irrigating, and wiping out infected areas of tissue with antiseptics, with the hope of sterilizing it, is so inadequate and ineffective that the object is defeated and little or no permanent good results are obtained; this is doubtless the experience of that section of the dental profession which asserts that it is useless to treat pyorrhea alveolaris when pus persists, after a trial of such superficial treatment, and asserts that extraction should be advised. There are even those who advise the extraction of *all teeth* which are affected with pus-yielding pyorrhea pockets. Mr. J. F. Colyer[1] says, "In cases where there is considerable bone destruction, or where in spite of local treatment the formation of pus persists, extraction of the teeth must be resorted to."

The reckless extraction of whole sets of teeth cannot be too strongly denounced; it is far more scientific to make every effort to save teeth affected by pus-yielding pockets. The writer is convinced that this can be systematically done by electro-sterilization in conjunction with surgical and other means as described farther on in this work. The promotion of asepsis in the pockets is of a permanent nature under favorable circumstances, and the duration of cure depends chiefly on the ability of the patient to carry out daily a regular system of hygiene of the mouth and stimulating the gums by brushing, etc. A few cases taken from the many hundreds of which accurate statistics have been kept, will be stated in order to make clear what is implied by the "cure of the disease."

Case A.—On March 30, 1904, Miss L., aged forty-five years, complained of a wide space appearing between central lower incisors; teeth otherwise perfect. Examination revealed a pus-yielding pocket, 5 or 6 mm. in depth, with nodules

[1] Dental Surgery and Pathology, p. 630.

of calculus, of hard dark variety, attached to the approximal surface of root. Treatment: calculus removed, root polished, electrical medication of pocket for eight minutes, tooth ligatured to next one with silk. A week later the periodontal membrane was perfectly healthy, all pus had disappeared. The patient has been seen periodically up to June, 1912. This pocket has never been reinfected nor has pyorrhea appeared in other parts of the mouth. This is the easiest class of septic periodontal infection to treat by ionization, it is always readily cured provided the displaced teeth are replaced in the normal position and ligatured for a time. One or two ionic treatments are usually sufficient.

Fig. 137.—Case B, before treatment.

Case B.—On February 9, 1898, Miss P., aged thirty-eight years; six superior incisors protruding; pyorrhea pockets on palatal surfaces extending to a depth varying from 1 cm. at the centrals to 3 mm. at the cuspids; teeth loose and discharge considerable; all other teeth slightly affected; no constitutional derangement reported. Treatment: all calculus removed and protruding teeth retracted by Angle's method of headgear and traction bar; during retraction the pockets were treated with 2 per cent. copper sulphate, 3 to 5 ma. current. Six treatments. At end of three weeks all signs of disease had disappeared. A retaining night plate

was inserted. The case has been seen once a year up to April, 1912, when model was taken (Fig. 138), the teeth were firm and gums perfectly healthy. Since then the patient has been seen yearly up to April, 1917, when the teeth were in perfectly good condition, the disease has never recurred.

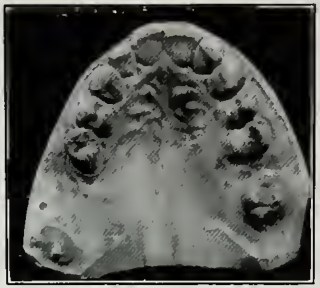


Fig. 138.—Case B, after treatment.

Case C.—This case is reported in the *British Dental Journal*, January, 1899, p. 2, and in the *Proceedings of the Royal Society of Medicine*, April, 1908, and will be briefly mentioned as a bad case of pyorrhea which has been cured for fourteen years. Miss R., aged twenty-nine years, consulted me in January, 1898, by her doctor's advice to have all her teeth extracted. History of thumb-sucking and mouth-breathing as a child. Superior incisors protruding nearly 2 cm. over the inferior incisors. Pyorrhea pockets on palatal aspect of superior incisors extended nearly to the apices; pockets of varying depth about every tooth in the mouth with considerable discharge of pus. Teeth exceedingly loose except molars. The patient was nervous and debilitated, suffering from alimentary toxemia. Treatment: loose bicuspid extracted; superior incisors retracted. Pyorrhea pockets treated with electric current with sulphate of copper and iodine. In eight weeks the pyorrhea had completely disappeared, but retraction of the incisors occupied about four months longer, during which time the case was

seen only once a month and the treatment continued. The teeth are retained by a wire arch attached to a plate worn at night only. In 1912 the mouth presented the appearance of

FIG. 139.—Case C, before treatment.

the model in Fig. 140. The pyorrhea has never returned in any part of the mouth, the teeth have been cleaned twice a

FIG. 140.—Case C, after treatment.

year regularly, but only a few further treatments with ions. The general health of the patient improved to a remarkable extent, and she now possesses a useful strong set of teeth.

The case has been seen recently (1917), the incisors are perfectly firm and free from disease; the first right upper molar only has been lost from caries.

These three cases were treated, at the time expecting cataphoric effects, but iodine and copper were used with the anode and kathode, and the writer now thinks the results obtained were due to penetration of ions.

Case D.—Mrs. H., aged forty-five years; every tooth of otherwise perfect set affected, pockets especially deep about the upper and lower molars where discharge was greatest. Teeth loose and patient's general health affected. Radiograph, Fig. 141, shows condition of the alveolus. The case

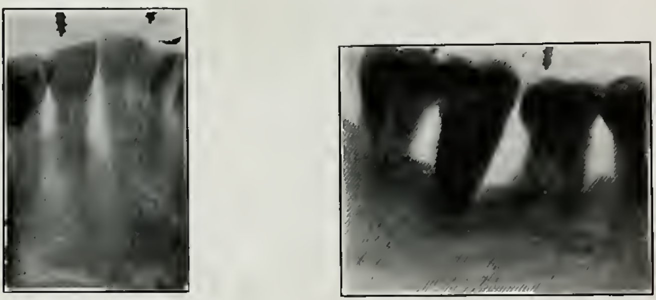


FIG. 141.—Case D. Radiographs of alveolus.

first treated Apil, 1907, twelve treatments with zinc ions. In five weeks the symptoms of the disease had entirely disappeared. After this one treatment a month was given until December 15, when the case was discharged cured. Since that date the patient has been seen twice a year and no recurrence of septic infection has occurred.

Case E.—Mr. C., aged fifty-five years, sent by a dental friend on October 7, 1907. Nearly all molars, upper and lower, lost from pyorrhea, the incisors had suppurating pockets on the palatal and approximal surface; patient's health affected. Teeth very loose. Treatment: eight treatments with zinc ions extending until December 19, when

the periodontal membrane was perfectly healthy; teeth firm, and patient's health perfectly restored. The case has been seen twice a year since, during which time there has been no recurrence of pyorrhea. The teeth were retracted to

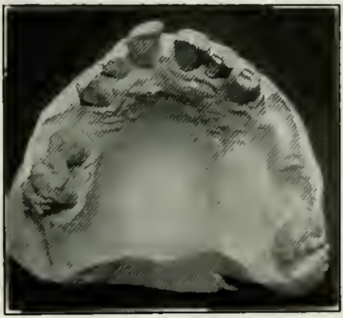


Fig. 142.—Case E, before treatment.

their normal positions, as shown in Fig. 143 taken five years later. In 1917 these teeth were still healthy and functional.

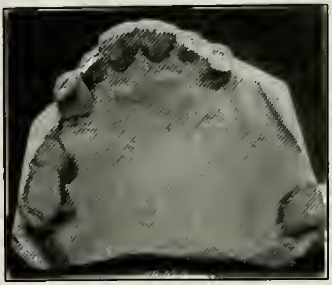


Fig. 143.—Case E, five years later.

There are a few of hundreds of cases which could be detailed, but it will suffice to quote these typical ones.

It is perfectly certain that in most of the cases here stated that such treatment as syringing the pockets or other forms

of irrigation would be quite inadequate to sterilize the tissues infected with pus-yielding microörganisms. It is true that replacing teeth when displaced by the disease is in itself a great aid in ordinary treatment, but this is not sufficient to bring about a cure.

The Zinc Ion.—The ion which appears to be the most sure and effective in sterilizing septic periodontal membrane and other forms of dental treatment, is the *zinc ion.* Of this ion Leduc[1] says: "This ion is an antiseptic of the first rank, and when applied electrically it can be made to penetrate the tissues of the skin to any desired depth. There is no wound or ulcer which cannot be disinfected by its employment, provided its surface can be reached by the electrodes." Many other eminent writers have classified this ion among the highly antiseptic, and abundant clinical evidence has been chronicled showing its great germicidal properties. Among those who make this important claim are Lewis Jones,[2] Finzi,[3] Marques and Pappon,[4] Bathurst,[5] Norman Bennett,[6] J. Forbes Webster, Fairfax Reading. The author has recorded in this and other works, the value of zinc ions in electro-sterilization and has no hesitancy in confirming the views of the writers mentioned, on the highly antiseptic properties of this ion. Recently, Prinz[7] has stated that zinc ions are devoid of supposed germicidal properties, but he has probably had little experience with this ion in sterilizing soft tissue and his assertion is not accompanied by any proof, clinical or otherwise, which might affect the evidence of the writers here referred to.

The Copper Ion.—The copper ion has also a strong antiseptic effect and answers very well for treatment of periodontal affections; copper electrodes have the advantage of being readily soluble by the electrolytic solution pressure,

[1] Lesions en Médecine, Arch. d'Elect. Méd., September 25, 1904.
[2] Ionic Medication, Chapter III.
[3] Proc. Royal Soc. Med., vol. ii, p. 140.
[4] Arch. d'Elect. Méd., p. 568.
[5] Klin. Monatschr. f. Augenheilkunde, November, 1908.
[6] Chronic General Periodontitis, Colyer, p. 99.
[7] Dental Cosmos, April, 1917, p. 388.

even a very small current of 1 ma. seems to readily cause dissociation of ions, a weak solution of copper sulphate provides a solution electrode rich in copper ions. The copper ion is particularly useful for fistulous tracts such as are often found in the mouth, because a copper probe is easily introduced into them, a zinc electrode being often too rigid and too large to enter the sinus without enlarging it.

The Iodine Ion.—The iodine ion is distinctly useful, and while possibly not so antiseptic as the zinc ion, seems to have a healing effect on the tissues. This ion is indicated when the tissues are nearly normal after a prolonged treatment with the zinc ion, also in treatment of the gingival trough in suspicious cases of threatened pyorrhea when septic infection has not yet caused the perceptible affection of the periodontal membrane. Many cases of periodontal disease can be averted by treatment with this ion.

The Silver Ion.—The silver ion is effective in the treatment of pulp canals and stomatitis, aqueous solution of silver nitrate being a convenient form of solution electrolyte. The staining properties of silver nitrate debar it from use about the front teeth, for although the ion itself is invisible, the preparation in excess is liable to stain the necks of the teeth. It loses its caustic properties by the electrolytic action. It is also a useful ion for obtunding sensitive dentine of the exposed necks of molars or cementum of roots of teeth.

Argyrol, a preparation of silver, possesses a distinctly sedative and soothing effect on gingival tissue when electrically applied. A solution of argyrol can be applied to the tissues without staining or caustic effects, and is useful in cases of hypersensitive gingivitis and sloughing of the papillæ of the interspaces of the teeth. Argyrol, however, is a colloid preparation and ions do not migrate readily if at all, but the therapeutic effect seems constant and is worthy of application even if ions are doubtful in this instance.

The Cocaine Ion.—This is readily introduced into the dentine of tooth structure by the current; any of the compound preparations of this drug act rapidly in producing anesthesia of live teeth. It can be introduced into the

structure of a tooth through a tiny opening, such as can be made by the finest spear drill which will drill through enamel. As soon as sensitive dentine is exposed the cocaine ion, with a current strength of 0.5 to 1 ma., will anesthetize the dentine in a few minutes, making it possible to drill nearly to the pulp, when a further application will anesthetize the pulp, so that it can be removed painlessly. The writer has only limited experience with cocaine ions on soft tissues, fearing the toxic effects that might be produced by rapid introduction of the ion in so good a conducting medium, but Leduc says: "The ion of cocaine introduced by electrolysis produces effects very different from those of a solution of the same drug injected subcutaneously. It produces anesthesia, but it does not diffuse, and the anesthesia remains strictly limited to the surface covered by the electrode. It would appear that the ion is introduced by electrolysis, not into the circulation, but into the plasma of the cells." This opinion, however, was negatived in one case in the author's experience, in which severe cocaine poisoning occurred when a very small dose of cocaine was introduced with the current into injured periodontal tissue in attempting to anesthetize the exposed pulps of a fractured tooth. Other cases of toxic effect of cocaine have been reported in American journals in which the effect was produced through the pulp alone with the current.

The Adrenalin Ion.—This is readily introduced into the tissues affecting the vascular system in the immediate area of application of the anode, in a very short time, producing the characteristic anemic appearance. The introduction of the drug by electrolytic method shortens the time required to produce the effect of blanching the tissues.

The Salicylic Ion.—This is said to have remarkable effects on facial neuralgia; cases which have resisted many other methods of treatment have been reported cured by introduction of this ion into the affected area. Lewis Jones[1] says about trigeminal perineuritis: "I have had a number

[1] British Med. Jour., August 31, 1912, p. 488.

of complete successes in the treatment of this condition with salicylic ions, and in general the results are so good that probably this has been the experience of all who have tried it." Leduc,[1] Dawson Turner,[2] and many others have published remarkable results in the treatment of neuralgia with salicylic ions.

There are, no doubt, a number of ions which have not yet been tried which will be found therapeutically of great value, those already mentioned have been tested and their effects properly demonstrated.

This method of treatment is within the reach of all practitioners, the apparatus which has already been described in other parts of this work in simple, inexpensive, and readily obtained; the technic is not nearly as difficult as many kinds of special work carried out by dentists. Thorough knowledge of the electrical phenomena applicable to electro-therapeutics is essential or the worker is liable to be puzzled by minor phases of the action of the current, which might interfere with persevering with the method, whereas when these are thoroughly understood, they are seen in their proper light and avoided or disregarded as of no vital importance.

The Advantages of Ionic Medication.—The advantages of ionic medication in dentistry are many. It is easily carried out; it is not nearly as painful as many other operations; it is effective; there are no ill effects; any discomfort caused at the time of administration disappears the instant the current is turned off; improvement is noticeable at once and is unmistakable by patient and operator; it places at our disposal a method of applying antiseptics, sedatives, stimulants, or styptics to a local area which act in concentration on the part medicated.

Effect of Ions on Bacteria.—The immediate effects of passing an antiseptic ion such as zinc, copper, silver, or iodine into an electrolyte, such as an area of periodontal tissue or a septic pulp canal, is the destruction of the microorganisms contained in the area through which the elec-

[1] Arch. d'Elect. méd., 1904.
[2] British Med. Jour., April 4, 1908.

trically charged ions radiate. This effect has been clinically demonstrated by many eminent medical workers in this special branch of electro-therapeutics. The author has found that inflamed periodontal tissue, yielding pus from infected pyorrhea pockets, becomes perfectly healthy when treated with antiseptic ions. In addition to this, constitutional symptoms, which so often accompany this disease, such as general malaise, headache, indigestion, anemia, laryngitis, pharyngitis, acneiform eruptions, and some forms of alimentary toxemia, subside and disappear altogether when they are caused (as they often are) by the absorption in the general circulation of the products of chronic suppurative conditions. It has been pointed out by exponents of vaccine therapy that the pus obtained from suppurating periodontal membrane contains a great variety of species of bacteria, that they are also found in the tissues of the affected area. Simms,[1] Goadby,[2] Eyre and Payne[3] have enumerated staphylococcus albus and aureus, streptococcus brevis and longus, micrococcus catarrhalis, spirilla and bacillus fusiformis and many other microörganisms but no specific organism. In administering vaccine prepared from organisms obtained from pyorrhea infection, the predominating organism or a mixture of organisms are employed with the hope of stimulating the production of antibodies (opsonins) of the corresponding variety to those responsible for the pathological condition existing and to render the patient immune by the injection of killed cultures of the suspected organism or organisms.

It is with a certain amount of diffidence that the author ventures to make the suggestion (not having investigated the subject) that by the destruction of microörganisms in suppurative periodontal tissue, by ionization, the antibodies are provided by subsequent absorption of dead microörganisms into the general circulation. It is further obvious that if these microörganisms in the tissues are,

[1] Observations on the Bacteriology of Pyorrhea Alveolaris, Tr. Odont. Soc. Great Britain, 1907, xxxix, 164.

[2] Trans. Odont. Soc. Great Britain, xxxvii, 145.

[3] Proc. Royal Soc. Med. (Odont. Sect.), December, 1909.

in their active state, responsible for the general systemic disorders accompanying the disease, the right organisms will always be provided; there will be no mistake on that point. The question arises whether the numbers of living bacteria to be found in the tissues and destroyed there by the ionic treatment are sufficiently large to affect the opsonic index.

However this may be, it is a fact that constitutional disorders which have arisen from the effects of existing chronic pyorrhea alveolaris usually disappear when the disease has been treated by ionic medication, and locally the tissues are restored to normal condition. Malaise will nearly always disappear before the disease can be said to be cured. This is a frequent experience of the writer in cases which have come under his notice.

It has been demonstrated experimentally by Breuer and Zierler, Lehmann, and others that the passing of a current alone has a sterilizing effect on cultures of bacteria in agar, and Zierler reports having put this into practice for sterilizing root canals, using small current of 3 or 4 milliampères, with satisfactory results.

Bethel has also shown that microörganisms infecting pulp canals can be destroyed by passing a current with nitrate of silver as the solution electrode, in which he doubtless obtained silver ions, but he attributes the effect to a combination of electrolysis and cataphoresis.

Hoffendahl also published similar effects on bacteria in the treatment of root canals with the current.

Josef Peter[1] has published his clinical experience in the same direction with the current and states that "the result was excellent in every case."

The author has used ions of zinc, silver, copper, or iodine for a number of years; he rarely fills a pulp canal without subjecting it to ionic treatment. Ions of zinc seem to be the most effective, a perfect sterilization of the canal walls is effected and septic disturbances after filling of the roots is practically impossible if this operation is carried out with due care.

[1] Dental Cosmos, vol. xlvii, p. 1136.

CHAPTER XI.

TECHNIC OF IONIC MEDICATION IN DENTAL OPERATIONS.

When a continuous current from the main is used, *the chair* in which the patient is seated must be insulated from all contact with earth. Most dental chairs have a large amount of metal about them, and if they rest on wooden or even carpeted floors fairly good contact with earth may be established, especially in very damp weather. A perfect insulation is effected by resting the metallic base of the chair on a rubber mat.

Water pipes or gas fixtures should not be within reach of, or be touched by, either patient or operator when the current is being used.

Metallic supports for cuspidors must not be touched if in contact with earth.

Saliva ejector must not be used with the patient in electrical contact; there is only a slight chance of contact with earth being established in this way, but it is best not to take the chance.

A continuous current either from a *switchboard* described (p. 95) or from a voltaic cell battery (p. 94) is the proper current for ionic medication.

The current at the starting point (zero) should be less than 0.1 milliampère. It must be so regulated by resistance in circuit that it can be increased in E. M. F. and in current strength by not more than 0.1 volt and 0.1 milliampère at a time. Current collectors which switch on one cell at a time increased the voltage and ampèrage too suddenly and should not be used for ionization of oral tissues.

A milliampèremeter is essential.

Conducting cords should be perfect and attached securely to the switchboard or battery terminals and to the electrodes; loose moving contacts produce disagreeable little shocks by occasional break of current.

The active electrode (p. 109) must be selected to suit the particular purpose for which ions are required.

In pyorrhea treatment metals corresponding to the solution employed or else of platinum must be used; platinum may be used with any solution, as it is not soluble itself. The area and cross-section of an active electrode influences the density of the current. Very fine electrodes are painful in periodontal tissue even with a small current; an electrode of 2 mm. x 1 mm. x 4 cm. tapering to the required size, just large enough to be admitted easily into the spaces of pockets to be medicated, should be used.

The solutions should be conveyed to the site of medication on absorbent wool tightly wound about the blade of the metallic electrode conductor, and wetted occasionally, as replenishing becomes necessary.

The electrode should be placed in position before raising the current from zero, the current should then be gradually increased until 2 to 5 ma. are registered and the patient indicates that a pricking sensation is felt in the tissues; it should then be reduced by 0.2 ma. and the electrode kept steadily in position for from one to five minutes according to the necessity for a large or small dose of ions. It should be the object to use as high a current strength as possible up to 15 ma. without giving undue pain.

The soft tissues are less sensitive to current than dentine at necks of teeth, the metal electrode should be kept away from sensitive teeth as much as possible. Intervals of treatment in pyorrhea alveolaris should be three times a week for first week, twice a week for second and third weeks, once a week after; this should be varied according to the severity of the case, it being best to vigorously keep up treatment at first until all pus disappears.

Metallic fillings in live teeth should be avoided when

possible. When impossible, small currents for a longer time should be used.

The current should be reduced to zero before removing the electrode from site of ionization or a painful shock will be experienced.

The shaft of active electrode should be insulated or not allowed to touch the cheek, lips, or tongue.

The saliva should be kept away by cotton rolls or napkins.

The indifferent electrode should be strapped to the patient's wrist or held by the patient or placed under the chin. It should always be covered with several layers of lint and should be moistened with water or a saline solution. If the metallic indifferent electrode causes blisters or smarts the skin, a carbon electrode in a glass dish of tepid water with a little chloride of sodium in it should be used. The carbon should be covered with lint and the patient's hand pressed firmly on it. (See page 109, Fig. 46.)

Rings should be removed from the hand holding indifferent electrode.

Electrodes should be held firmly and contact over as large an area as possible insured.

The poles should be tested in all new switchboards or batteries (see p. 42).

When *acid radical* ions are required, a lower current strength will be indicated, as the negative pole is more painful with small electrodes than the positive.

It is best to begin with a low voltage and current strength, as it will be found that the resistance of the body becomes less as the séance goes on, and highly susceptible patients will stand more if this precaution is observed.

The principles peculiar to the movement of ions referred to on p. 233 must be observed.

For anesthesia of dentine or pulp active electrodes of as large an area as possible must be used. The metal conductor must not be brought in contact with the dentine or pulp; cotton-wool saturated with the anesthetic should first be placed in the cavity and the electrode pressed firmly on this. The area of the electrode can be increased by

placing a piece of platinum foil over the wool and attaching the electrode to this.

Resistance in dentine is great, therefore the E. M. F. required will be great, and current strength required much less than in dealing with soft, moist tissue; 0.5 ma. will sometimes be painful but this amount of current is often sufficient to anesthetize dentine, or it may be raised to 1 or 2 ma. after a few minutes' séance. When the pulp becomes anesthetized a current of 3 or 4 ma. will give no sensation, and this is a sign that the pulp may be drilled into without pain.

For sterilizing pulp canals, the electrode of fine iridio-platinum wire should be passed into the canal or canals, a solution of antiseptic to be used must be introduced into the cavity on cotton-wool, and the canal flooded with it. Current strength and time required to sterilize the canal must be in direct ratio: if 2 ma., 15 minutes; if 3 ma., 12 minutes; if 4 ma., 8 minutes; if 5 ma., 5 minutes; this is approximately a good working basis.

For treatment of fistulous tracts, a soluble copper electrode should be passed into the fistula and to this, *in situ*, a platinum or copper active electrode connected. A current of 3 to 5 ma. is usually bearable. Five minutes will furnish a dose of copper ions sufficient to sterilize the tract. The pulp canal should be sterilized also as above described. The soft tissues will adhere firmly to the electrode; it should not be forcibly removed, the tissues will relax their hold in a short while, and if not, reverse the poles and pass a negative current for about half a minute, this will loosen the electrode.

For bleaching discolored teeth a platinum electrode should be used and the patient can hold the indifferent electrode, or the more effective method is to place the two electrodes of platinum wire in the tooth, separated there by as far a space as circumstances will allow and interpose cotton-wool saturated with the bleaching compound in solution.

Care must be taken not to short circuit the current either within the tooth or without by allowing electrodes or wires to

meet. By this method with fine electrodes 5 ma. current produce some heat, 10 to 15 ma. produce intolerable heat in the tooth when the bleaching material becomes dry.

The tooth should be isolated by applying rubber dam. Metallic fillings should be removed. Fine platinum wire electrodes produce more heat than thick wires. The poles should be reversed with the electrode *in situ*, when the operation is about half completed.

CHAPTER XII.

HIGH-FREQUENCY AND STATIC CURRENTS.

X-ray and High-frequency Currents.

THESE currents are much used in medical electricity for general electrification of the body, and for local application. The effects are of a mixed character, acting largely on the nervous system, circulation, respiration, and as d'Arsonval has shown, on microörganisms.

Therapeutically these currents are applied in many special ways for treatment of diabetes, gout, rheumatism, tuberculous glands, neuralgia, pyorrhea, and many other local and general diseases. Mr. L. C. Creasy[1] advocates a special form of static application for treatment of glands which are enlarged by the absorption of toxins from the teeth—lymphadenitis. This he terms Intensive Irradiation and Static Wave Treatment. The treatment consists in first treating the affected area by intensive irradiation from a 500 candle-power incandescent lamp with special reflecting properties, this increases local metabolism and elimination. The static wave current is then applied with the object of increasing physiological resisting power of the parts. "Passive congestions are removed by improving the physiological 'tone' of the affected region."

This method of applying the static wave current is best described by quoting the words from that author who quotes Potts: "The patient, on an insulated platform, must be connected to the side of the static machine that is not grounded. The electrodes should be of pliable metal and the treatment should be commenced with the prime

[1] The Practitioner's Encyclopedia of Medicine and Surgery.

conductors practically closed. On drawing the prime conductors apart the wave current will become apparent and as wide a spark should be used as can be easily tolerated by the patient."

This form of treatment for glands affected by toxins from teeth or gums is a distinct advance on anything so far recommended outside of surgical treatment for acute and chronic lymphadenitis.

Much controversy has arisen as to how these glands are affected, and as to the correct diagnosis of lymphadenitis, but outside of aseptic oral treatment nothing seems to have been recommended for treatment in chronic cases.

High-frequency currents have attracted little attention. They have, however, been used on the Continent with considerable success in the treatment of acute periodontal disease. It is claimed that this oscillating current has an ionic effect on solution electrodes placed on the tissues.

Dr. William Dunn, of Florence, has pointed out that high-frequency currents possess valuable therapeutic properties which are singularly adapted to the treatment of pyorrhea alveolaris. He points out that the stimulating, antiseptic, and antitoxic properties of high-frequency currents are especially indicated in the treatment of diseased tissues in which the pathological conditions are accompanied with depressed or lost vitality or with a disturbance of metabolic functions. Together with his colleague, Dr. Luigi Arnone, of Florence, good results are claimed from high-frequency treatment of pyorrhea, using the currents as an auxiliary after surgical treatment of the disease, he says, "In every case with marked beneficial effects, the gums toning up and looking healthy and hard in a short time, pus ceasing more rapidly than before, and the teeth bracing up rapidly." Dr. Dunn also puts forward the anesthetic effects of high-frequency currents in dental treatment, pointing out the great usefulness of this property of these currents in cases where cocaine is contra-indicated, he says, "sufficient anesthesia has been obtained locally to perform painlessly some of the minor operations, such as lancing gums, removing roots, etc."

Other workers in this special electrical branch have reported successful anesthetic effects from high-frequency currents, among them Dr. Didabury claims a high degree of success.

A form of high-frequency treatment which is called by the author, Monsieur F. Morel,[1] of Dreux, "alto-frequent effluvation," has been described by him as having remarkable effects in the treatment of pyorrhea alveolaris by the formation of what he terms "mixions." In the following description of the action of these currents he says: "This effluvolysis does not, like electrolysis, have for its result a simple transport of the ions which travel respectively toward the positive or the negative pole, but there is produced in consequence of the frequent periods, molecular vibrations to which these periods give rise—vibrations which constitute a veritable ionic bombardment. It is no longer a question merely of cathions or anions; all these ions clash together, mix, unite, and combine to form new molecules of a different chemical formula from the primitive element. The exchange of the ions is cathodic and anodic at the same time at the point of application of the effluves; I will call the molecules thus newly formed '*mixions.*' "

Monsieur Morel states that he has experimentally introduced ions into the bodies of animals by this method of alto-frequent effluvation and produced in them therapeutic effects characteristic of the ion used, cyanide of potassium and oxalate of strychnine producing convulsions and death to guinea-pigs.

Reading the action of the ions formed by the effluvolysis of bichromate of potash he gives the following formula:

$$Cr_2O_7K_2 + 4H_2O = \text{anions } \frac{O}{H} + \text{cathions } \frac{Cr}{K} = \text{mixions } \begin{matrix} CrO \\ HO \\ KOH \end{matrix}$$

which shows that the chemical composition of the bichromate of potash and water is changed by the effluvolytic ionization into chromic acid ($2CrO_2$) + caustic potash ($2KOH$) + water (H_2O), and for them he claims antiseptic and

[1] Bulletin du Syndicat des Chirurgien-Dentistes de France.

stimulating effects from the chromic acid, and solvent properties on tartar for the caustic potash. The effect he claims is a perfect medication of "mixions" which are not eliminated from the tissues for some days; he states that "urologic analysis does not reveal to us the presence of the medicament until twelve hours after effluvation, and does not become eliminated before the end of two days.

In addition to the antiseptic effect of the ions, a stimulating effect in the protoplasm of cells is produced and a further antiseptic effect from the production of ozone at the contact of the electrode.

The technic of this method of treatment is briefly as follows:

The gums or necks of affected teeth are painted with a solution of

Fluosilicate of soda . . .	2 gm.
Chloride of ammonia	1 "
Chloride of potassium . .	11 "
Salicylate of theobromine . .	1 "
Methylal	50 cgm.
Distilled water .	20 gm.
Filter.	

A pad of cotton-wool saturated with a solution of bichromate of potash in water 1 to 10 is placed over the necks of 4 teeth at a time and on this pad is placed the empty electrode of the alto-frequent current; this is pressed firmly but not roughly into place, and an "alto-frequent rain of effluves" is passed into the tissues.

In advanced pyorrhea cases a metallic electrode is used which projects about ten sparks in the infected pockets. The operation of effluvation lasts for five minutes at a time and three such are given: this is repeated every two days for six visits. Metal fillings must be insulated by covering them with gutta-percha, to protect against pain which the current would otherwise cause.

X-rays and High-frequency Currents.—From time to time reports have been made in the journals of the good results obtained by the combined use of *x*-rays and high-frequency

currents in the treatment of pyorrhea alveolaris. Dr. C. H. Parker,[1] of Chicago, in 1903, advocated the use of *x*-rays for one or two minutes and then high-frequency for five minutes, having previously sprayed the affected gums with a mixture of iodine, aconite, myrrh, and wintergreen. He says: "The object of spraying the gums with medicament before turning on the *x*-ray and high-frequency currents on the patients is to have the chemicals carried into the tissues by these currents." His method of applying the high-frequency electrodes over the mouth of the patients also has the effect of saturating the tissues with ozone which by its high oxidation properties increases metabolism and elimination with consequent improvement in the condition of stasis which attends the disease. From this method of treatment very good results were obtained.

Dr. F. LeRoy Satterlee, Jr.,[2] of New York, improved on the method of applying the high-frequency currents to pyorrhea teeth by applying the vacuum electrode directly to the gums, and agrees with Dr. Parker on the results obtained by this treatment, he says: "This treatment in combination with *x*-rays has proved very successful in a number of cases, and in the early stages of pyorrhea where the alveolus has not been entirely sloughed away we may claim a complete cure, the teeth tighten up, with restoration of the gums to a healthy condition." Two years later Dr. Le Roy Satterlee,[3] after further testing the use of *x*-ray and high-frequency currents in the treatment of pyorrhea, says: "I have derived the best results from a combination treatment of *x*-rays and the use of special vacuum electrode of my own design that conveys the high-frequency currents and at the same time bathes the gums and underlying tissues in the rich radiations of the bi-ultra-violet rays. A metal electrode is meanwhile held in the hand to complete the circuit through the body of the d'Arsonval currents."

S. Tousey,[4] of New York, advocates a combination of

[1] Dental Cosmos, xlv, 947.

[2] Ibid., xlvi, 642.

[3] Ibid., xlviii, 274.

[4] Medical Electricity and Röntgen Rays, p. 569.

x-ray and high-frequency currents for the treatment of pyorrhea alveolaris. A specially prepared x-ray tube with the rays localized to an opening in a shield of $2\frac{1}{2}$ inches is used. "The rays should be about No. 4 of the Walter or of the Benoist scale, the resistance equal to a parallel spark of about 2 inches, the primary current about 3 ampères, with a 12-inch coil and Wehnelf interrupter and a current of 2 ma. passing through the x-ray tube. The anticathode of the tube is about 10 inches from the face, the lips are open, exposing the teeth and gums, and the time of exposure is from one to two minutes." The x-rays escape only from this

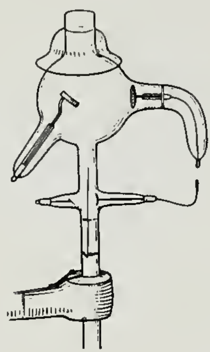


Fig. 144.—Tousey's x-ray tube for treating pyorrhea.

special tube at the end of the prolongation and the strength of application is much reduced as compared with the ordinary x-ray tube. Treatments are given to the affected gums twice a week, immediately followed on each occasion by high-frequency currents, applied by vacuum electrodes especially prepared for this purpose, which fit the different aspects of the alveolar border and necks of the teeth. The high-frequency is applied for thirty seconds to one place and then moved to another. The usual ozone effect is noticed about the electrode and the application is said to be entirely painless.

Tousey says: "The results are very prompt relief of pain and improvement on the ulceration, so that in three weeks

the dentist almost always reports that the teeth are better than for six months previously. The teeth gradually tighten up and the tenderness disappears."

He recognizes that there are many forms of pyorrhea and that the best results are not obtainable in some forms of the disease by this combined *x*-ray and high-frequency method. Those cases which are dependent on constitutional complications would be contra-indicated. It must, however, be kept in mind that the *x*-rays are very destructive rays to tissues and too long exposure might result in burns, even with as low a current as here recommended. The danger to which the operator is constantly exposed must also be remembered, and special attention is drawn to this in dealing with the technic of Dental Radiography in another chapter of this work (p. 148).

CHAPTER XIII.

ELECTRO-THERAPEUTICS IN DENTISTRY.

Treatment of Root Canals—Periodontitis from Septic Pulp—Acute Local Periodontitis—Alveolar Abscess—Trismus from Impacted Third Molar—Chronic Alveolar Abscess—Perforation of the Root—Necrosis of the Jaws—Marginal Gingivitis.

Treatment of Root Canals.—The sterilization of root canals which have become septic by death and decomposition of the pulp, in which microörganisms infect not only the canals but also the tubuli of dentine, is by no means an easy matter to accomplish, as may be deduced from current literature on the subject, in which therapeutic agencies of the most powerful antiseptic type have been recommended from time to time, only to be rejected after trials, when it is found that secondary manifestations of septic infection occur in spite of their use. This experience is due to the osmotic method of application, by which the sterilizer does not reach deep-seated bacteria in the tubuli or apical foramen. Sterilization by ionic medication overcomes this difficulty by the migration of ions into the tubuli and along the most tortuous or constricted root canal to the apex, as can be experimentally demonstrated by the following experiment.

Take a freshly extracted tooth, cleanse the root canal of all débris of pulp, fill the pulp chamber and canal with 5 per cent. solution of ferrous sulphates, insert a fine, smooth, steel nerve instrument into the canal as far as it will go toward the apex, insert the tooth up to the neck in a small sponge in a porcelain dish containing tap water. To the nerve instrument in the canal connect the positive pole of the generator and to the sponge connect the negative pole. Turn on the current and allow 5 ma. to pass for 5 minutes. Turn off the current, remove the instrument and wash out the canal

thoroughly with tap water, saw through the root transversely, and place the sections in 10 per cent. solution of ferricyanide of potassium for four hours. The canal to the apex and the tubuli will be seen stained Prussian blue; sections cut transversely across the root will demonstrate that ferrous ions, which are colored blue, have penetrated a considerable distance into the tubuli (in the case of a young subject to the very ends). This demonstrates that by passing a continuous current for a given time the conducting ions of a metallic salt are transported by the laws of conduction into the tubuli of dentine and through the apical foramen into the surrounding tissue. The depth of penetration will in some measure depend on the organic matter in the tubuli and the size of the opening at the foramen, as well as the current strength available.

The electrolytic dissociation and migration of ions has been explained, and it has been shown that the ions are the conductors of current. This theory when applied to the electrolytic sterilization of root canals is dependent for its success on two factors: (1) The employment of adequate current strength or energy to dissociate a sufficient dose of ions from the electrolyte used in a given time; the time must be calculated in direct ratio to the current strength. If only 2 ma. current is tolerated by the patient, fifteen minutes will be required; if 3 ma., 12 minutes; if 4 ma., 8 minutes; if 5 ma., 5 minutes. For practical purposes this ratio provides a working basis, which is desirable in electrical treatment. (2) The employment of an electrolyte, which when dissociated by the current, the conducting ions are of an antiseptic nature. This is an all-important factor, which can be determined by experimental and clinical evidence, the latter must be based on actual experience extending over a considerable time and not only from a dental but also medical stand-point. Sufficient clinical evidence has been recorded to place ions of zinc, copper, silver and mercury in the category of highly antiseptic ions, as has been already referred to (see pp. 234 and 244) from a medical and dental aspect. For root sterilization the author has had most success with zinc and silver ions.

Recently Prinz[1] has propounded the theory that zinc ions have no germicidal properties and claims that for root sterilization chlorine ions from chloride of sodium is more effective than any of the above salts, and quotes various experiments as evidence. He says "zinc ions are devoid of supposed germicidal properties" but gives no data of his experience with this ion from a clinical stand-point, probably having had none. E. Zierler (1905) first brought forward the claim that sodium chloride solution electrolytically applied sterilizes root canals. Both these authors disregard the principles of ionic medication by dissociating sodium ions or chlorine at the anode and relying on the anion chlorine which does not move away from the positive pole but is simply eliminated, it therefore does not penetrate the dental tubuli to any depth, it is the sodium (kathion) which is conducted by the current in passing. It is therefore highly improbable that the full sterilizing properties of chlorine are available with this technic, sterilization being only possible on a very superficial area of the wall of the root canal so treated.

The operation of electrolytic sterilization of root canals is briefly as follows: The patient is seated in an insulated chair; the tooth to be treated is cleansed from all débris of dead pulp, the opening to the pulp chamber being freely enlarged to admit of electrolyte and electrode. The canal should be enlarged a short way to admit the electrode and care taken that débris of inorganic matter does not make an obstructing plug to the passing of current through the length of the canal. The tooth must be kept free from moisture from the mouth by rubber dam during ionization and after until the cavity is sealed. The root canal should be flooded with 3 per cent. zinc chloride and a fine iridio-platinum electrode inserted as far as it will go toward the apex, but not through the apex. The electrode should be securely attached to an insulated hand-piece and connected with the positive pole. The patient should hold the indifferent electrode, which should be of large size and covered with

[1] Dental Cosmos, April, 1917, p. 388.

several layers of lint moistened with saline solution. The current should be at zero and not turned on until the electrodes are firmly in position, the rheostat resistance should then be gradually and slowly released, and the patient instructed to indicate when the current is felt in the tooth by raising the hand; this may occur at 2 or 3 ma., when it should be reduced $\frac{1}{10}$ ma., and kept at this for half a minute when usually it can be increased about 1 ma., or if greater current strength is tolerated it should be taken advantage of. The time is then noted and sterilization effect judged in direct ratio of time to the current strength in use, according to the working basis given already.

FIG. 145.—Premolar with electrodes in position for ionization of roots.

A two- or three-rooted tooth can be treated at one time by inserting wire electrodes into each canal and connecting them together securely (see Fig. 145). When sterilization has been completed the current should be reduced to zero and the electrodes removed, a dressing of cotton-wool saturated with the zinc chloride solution should be inserted into the canals and the cavity carefully sealed with gutta-percha. This dressing should remain for two or three days when the canal can be filled after again sterilizing it as before, as a precautionary measure, especially is this second dose of ions indicated if there is any evidence that at any previous time periodontal inflammation has existed.

Periodontitis from Septic Pulp.—The complication of periodontitis following the death of the pulp, indicating that septic infection has passed through the apical foramen, requires great care in obtaining a sterile root to prevent recurrence of periodontal inflammation. The decomposed pulp tissue should be removed as thoroughly as the tender tooth will allow and the canals electrolytically sterilized at the first treatment as thoroughly as possible without resorting to rubber dam or the use of drills in the inflamed condition, an antiseptic dressing lightly inserted and the cavity sealed with varnish wool for twenty-four hours. At the end of this time, or when the inflammation has subsided sufficiently, the canals should be enlarged and thoroughly cleansed; zinc ions should be introduced with the same technic as described for treatment of root canals, the canals and cavity sealed in the same way, and the patient dismissed for a week, at the end of which time if every sign of inflammation has disappeared, the root should be again sterilized with zinc ions and filled permanently, or if not quite free from inflammation it should be filled temporarily, and the patient dismissed for a few days, when it should be finally sterilized and filled.

Silver ions electrolytically dissociated from a 2 per cent. solution of nitrate of silver are also effective for sterilizing septic roots of this kind, but on account of the staining properties of this preparation its use must be confined to back teeth.

The most favorable cases are those with large canals or canals which are easily enlarged to the apex, which admit an electrode to the end of the root. Ions pass readily through these and sterilize the tissue, destroying bacteria which have infected them and caused the inflammation.

A case typical of the effect of electrolytic sterilization may be cited. A patient, the brother of a dentist in America, had acute periodontitis in a lower premolar which was filled temporarily. This tooth, the patient informed me, could not be permanently filled because he "so often had to have the root treated." The filling and root filling were readily

removed, and the root was electrolytically sterilized with zinc ions, with 4 ma. current strength for eight minutes. The inflammation subsided that day, and two days later it was again sterilized in the same manner and the root canal and cavity filled. This treatment effected a permanent cure of the trouble. The root has now been filled for five years without recurrence of inflammation. The patient's brother wrote me for information of this method of treatment, saying a cure had been effected in one of the most troublesome cases he had ever had to deal with.

Acute Local Periodontitis.—This condition is due to septic extension from the pulp and is the continuation of periodontitis just described, which terminates in suppuration and formation of alveolar abscess. If the abscess has not attained large dimensions and the apical foramen will admit of evacuation of pus through the root canal, successful and rapid termination of the abscess can be carried out by electrolytic sterilization as follows: First syringe the canal to remove all septic matter and evacuate all pus and blood available, then flood the canal with 3 per cent. zinc chloride and insert a few shreds of cotton-wool soaked with the solution to hold the supply of solution in the canal. Pass a fine iridio-platinum electrode to the apex of the canal and perform electrolytic sterilization in the same manner as described in the foregoing treatment for periodontitis. A large dose of zinc ions will be required, and it is advisable to extend the time, in proportion to current strength rule, to a couple of minutes longer than for ordinary root sterilization. In this way zinc ions are introduced into the abscess area, and will often terminate an abscess in less time than the ordinary method of sealing antiseptics in the root canal. After the first treatment a cotton dressing with some antiseptic oil, like dentalone or oil of cloves should be inserted until the next day, when this should be removed and the canal thoroughly syringed and cleansed with nerve instruments with the object of evacuating any pus or blood that might remain, and also removing all the essential oil present. The sterilization should again be carried out as before.

In addition to this the inflamed area immediately over the root of the tooth should be treated by applying a weak aqueous solution of tincture of iodine (one part tincture and ten water) on cotton-wool and pressing it into position with a flat platinum electrode 3 or 4 mm. wide, then reverse the polarity and ionize the application with the negative pole, the patient holding the positive pole. It will be noted that the iodine will be bleached white as the process of driving the ions into the tissue proceeds. The time required to do this will be five to eight minutes, according to the amount of iodine liquid contained on the wool. This treatment of the surface area with iodine ions should be repeated when sterilizing the canal and abscess as long as the inflammatory symptoms are present.

Referring to this method of treatment of the surface area over the root Dr. J. M. Fogg,[1] of Philadelphia, states that the current has been to him of greater value than in any other class of cases, and that "in most cases one application is all that is necessary to reduce the inflammation, the pain quickly subsides, and there is seldom a recurrence of the disorder." The author has also found that this external treatment in abscess cases is a great help and relieves the pain effectively.

Alveolar Abscess.—When an acute abscess at the apex extends through the bone into the overlaying soft tissues, treatment through the root canal is obviously impractical and the usual course of lancing and evacuating the pus must be resorted to. The healing of the abscess can be greatly facilitated after evacuating the pus by syringing through the opening in the soft tissue with warm 2 per cent. solution of zinc chloride, filling the abscess with the solution and introducing a zinc probe electrode into the area, attached to the positive pole, the patient holding the negative electrode; a current of 3 or 4 ma. can usually be tolerated, and five minutes' ionization of the abscess area will sterilize the parts and assist greatly in relieving the condition. In addition, as

[1] Dental Cosmos, xli, 27.

soon as it is possible to treat the root canals, electro-sterilization should be carried out as described previously for periodontitis, and the root filled with the same technic. This treatment is effective in preventing the subsequent development of a fistulous tract or a chronic abscess sac.

In cases of mandibular teeth affected by alveolar abscess, which threatens to gravitate to the outer surface of the jaw ionic medication is specially indicated to furnish a lasting and effective antiseptic dressing, and a means of arresting the progress of breaking down of the soft tissues.

Trismus from Impacted Third Molar.—Abnormally placed or impacted mandibular third molar frequently causes infection of the soft tissues surrounding the crown, by the formation of a pouch or pocket, into which débris of food collects and decomposes, resulting in ulceration and sloughing of tags of gum, extensive inflammation and condition of *trismus* occurs. The writer has found ionic medication in these cases of the greatest value, particularly in relieving trismus, which appears to be caused more from a reflex action of the nervous system, than from inflammation of the muscles. The limitation of movement of the mandible can be invariably relieved as follows: Syringe the affected area to remove loose débris of food and pus, then wrap a zinc electrode with cotton-wool, and saturate it with 3 per cent. chloride, pass the point of the electrode to the bottom of the pocket or under the flap of gum, so as to medicate the ulcerated area, pass 3 to 5 ma. current from the positive pole for five minutes. If the space available between the teeth is insufficient to admit the electrode, a well-curved electrode can be passed between the cheek and the teeth into the pocket or space, but as the cheek is likely to touch the electrode and increase its conducting area, a larger current will be required to sterilize the affected part, 5 or 6 ma. for five minutes will often be tolerated, and is advisable. This will relieve the trismus considerably in twenty-four hours, and by repeating the treatment daily, with frequent use of an antiseptic mouth wash, the inflammation will subside, and the trismus be reduced to such an extent that in a few days it is

often possible to operate for the permanent relief of the condition.

A case in point recently under treatment is typical and lends itself in support of the writer's conviction that these cases of trismus are entirely due to nerve reflex, either directly by the influence of the inflammatory irritant on the vaso-neural circuit or indirectly by absorption of toxic products, or a combination of both these. A medical practitioner brought a young lady in consultation for what he suspected might be pyorrhea. Glands of the neck on the right side had

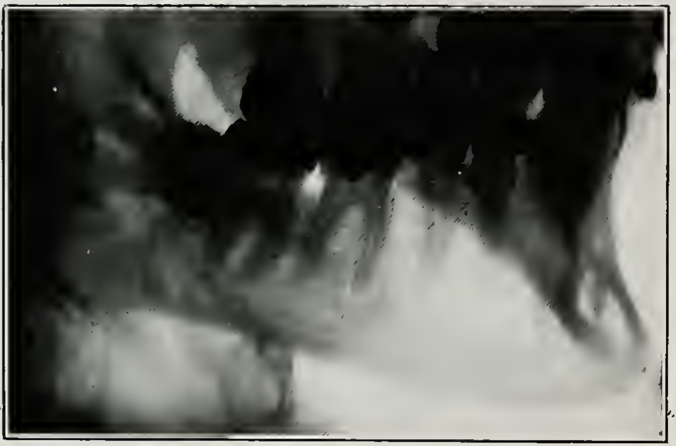


Fig. 146.—Impacted third molar.

been operated on twice, and another operation was impending; temperature was 100° to 101° at night; exceedingly nervous; very foul breath; teeth decayed in several parts of the mouth and hypersensitive; very *marked trismus* which had existed for six months during which time limitation of movement had varied considerably; at this time a forefinger could just be passed between the front teeth, the angle of the jaw on right side enlarged. A large septic pocket existed behind the second mandibular molar through which the crown of the third molar could be felt with a probe. Radiograph showed the third

molar placed horizontally against the crown of the second molar. (See Fig. 146).

Treatment by ionic medication with zinc ions, as described already, improved the condition of trismus in five days, so that it was possible to clean up the mouth generally; the temperature became normal in two days after the first treatment, in seven days inflammation had almost subsided, and the mouth could be opened sufficiently to easily admit the forceps when the second molar was extracted. The nervous affection subsided, the glands got normal. Relieving of the trismus in this case was of the greatest value in bringing about a rapid cure of what might have been a prolonged and distressing condition.

Chronic Alveolar Abscess.—Chronic alveolar abscess in which a fistulous tract is formed from the root of the tooth, opening on the gum, with suppuration constantly or at intervals, is frequently seen in the mouth, and is often difficult to cure. The condition is usually caused by septic infection of the pulp canal which supplies toxins and keeps up the suppurative process.

Treatment by electro-sterilization consists in opening the pulp canal to the apex and filling the canal with 3 per cent. zinc chloride or 2 per cent. silver nitrate, then with a little cotton-wool to retain the solution in the canal, pass a fine iridio-platinum electrode to the apex and pass 3 to 5 ma. current from the positive pole for five to twelve minutes, according to current in use, reduce the current to zero and seal the canal temporarily with dentalone on cotton and a tight gutta-percha filling in the crown cavity. Pass a copper probe through the opening on the gums the length of the tract till it reaches the root of the tooth, attach the positive pole to this and pass 3 ma. current for eight minutes; a useful size probe is thick copper bell wire and a small hollow coil can be made at one end to receive and steady the hand electrode by winding the wire around the shaft of a steel excavator (see Fig. 49). On turning off the current the tissues will be found to adhere to the probe, this can be released at once by reversing the poles and passing 1 ma. for one

minute, or by waiting a few minutes the contracted tissue will release its hold. The tract will be stained green from cupric ions imparted. These ions, which are highly antiseptic, are due to a secondary reaction, which takes place about the soluble electrode, the result of electrolytic solution pressure on the copper with the tissues as the electrolyte.

Often a single treatment of root canal and gums by this electro-sterilization method will permanently cure a chronic abscess, but before filling the root canal permanently it is best to test the efficacy of the medication by waiting a week, and then sterilizing the canal again before filling it, or in case the tract still discharges to do both again and wait another week.

If the sinus extends to the skin on the outside of the face and it is desired to save the tooth, the process of electro-sterilization of root canal with zinc ions and the tract with copper ions as already described can be effectively done. These cases may be accompanied by cicatricial adhesion of the sinus by a fibrous cord to the surface of the bone, resulting in an ugly scar. Lewis Jones,[1] Leduc and others have pointed out the sclerolytic action of the current with chlorine ions, and while it does not seem certain whether the chlorine ions or hydroxyl (H. O.), which is also liberated at the surface of the negative metal electrode, is responsible for softening scar tissue, some very remarkable results are recorded of improvement in scars and cicatrices following chlorine ionization, and the author would refer his readers to Lewis Jones's work *Ionic Medication* for further information.

Perforation of the Root.—When the apex of a root has been perforated in the operation of drilling the canal, septic matter is likely to be introduced into the periodontal tissue, and in spite of ordinary antiseptic precautions inflammation is likely to occur. To prevent this, perfect sterilization can be ensured by electro-sterilization with 3 per cent. zinc chloride or 2 per cent. copper sulphate, passing the iridio-platinum

[1] Ionic Medication, p. 137.

electrode to the apex or slightly through, and passing 3 ma. current for five minutes. The apical foramen being open, conduction of current is much greater with a small current than in a small unopened foramen with a larger current, so that sterilization is effectively carried out with a small current strength in a short time.

Perforation of the side of the canal or at the floor of the pulp chamber is an accident which may occur in crooked or constricted roots and in large cavities extending toward the bifurcation of roots. It is a condition which is regarded by many as hopeless. J. F. Colyer says,[1] "When the side of the canal has been perforated there is but slight chance of saving the tooth." Until the author tried ionic medication in these cases he found great difficulty in saving these teeth, especially if perforation had occurred some time previously and had been the cause of periodontal inflammation, but electro-sterilization of the perforation and the whole canal has been very successful and proved that perfect sterilization and proper subsequent treatment is all that is required to save such teeth. Zinc or copper ions with 3 ma. current for five minutes imparts a sufficient dose of ions to sterilize the soft tissues beyond the artificial opening. A plug of soft gutta-percha impregnated with a little iodoform and moistened with dentalone on a warm slab, making a thick paste which subsequently hardens, should be introduced into the opening to fill it, and the canal filled with gutta-percha. The soft tissues tolerate this medicated gutta-percha, and usually the condition about the root becomes normal and the tooth comfortable. Dr. J. W. Spaulding,[2] of Paris, has advocated the use of a lead point to close the perforation, and records success from the use of this material.

Necrosis of the Jaws.—Necrosis of the jaws in private practice is most often seen in the alveolar process, and is generally caused by septic infection following traumatism, arsenious acid poisoning, or chronic septic infection of the apices of the teeth. In these cases the sequestrum should be

[1] Dental Surgery and Pathology, p. 546.
[2] Dental Cosmos.

removed, if separated, or the surface of the necrosed bone burred away and the débris syringed out, the affected area should then be sterilized with zinc ions at first if there is considerable discharge, and followed later with iodine ions. A zinc electrode wound with cotton-wool saturated with 2 per cent. solution of zinc chloride, introduced into the tract and 5 ma. current passed from the positive pole for eight to ten minutes, according to the extent of the necrosis, will impart a sufficient dose of ions to sterilize the part, and greatly reduce the sepsis. When discharge is reduced, iodine ions are useful in promoting healing; 10 per cent. aqueous solution of tincture of iodine conveyed on cotton-wool wound about a large platinum electrde with a current of 5 ma. for eight to ten minutes according to the severity of the case, using the negative pole.

In chemical poisoning cases from arsenious acid which has leaked from a cavity in devitalizing the pulp and caused a necrotic area of gums and alveolar border, the affected part should be freely cut away with a sharp round burr and syringed with warm water; then a platinum electrode wound with cotton-wool and saturated with 10 per cent. tincture of iodine and water applied to the part and 2 ma. current passed from the negative pole for five minutes. This will often arrest the necrosis after a single treatment and terminate a painful and threatening condition.

More extensive necrosis of the alveolus can be treated in this manner with zinc and iodine ions to arrest the spread of sepsis and shorten the period of healing, and is more effective than ordinary irrigation methods.

A case to illustrate this may be mentioned. A lady was sent to me by a throat specialist with necrosis of the alveolus extending from the first premolar to the first molar in the maxilla on the left side. The first premolar had been extracted and a hollow tube inserted into the socket, supported in position by a small gold plate. She had worn this plate for many months, and was quite expert in syringing out the affected tract, which she did many times a day. She was certain that she could not do without the drainage tube

for twenty-four hours as "the pain would be intense," and nearly refused treatment when I refused to allow her to replace it after the first treatment. The area of exposed bone was narrow and about one inch long. Electro-sterilization with zinc ions introduced by flooding the area with 2 per cent. zinc chloride and a zinc electrode wound with cotton-wool and saturated with the solution passed into the opening; 4 ma. current from the positive pole for ten minutes was the daily treatment for a week. At the end of this time no pus was present, and the tract was nearly closed. Iodine ions were used for another week, and the lesion healed completely. The patient's general health was bad, and the doctor suspected toxic poisoning from the sepsis in the mouth aggravating existing rheumatoid arthritis.

The author has not tried the effect of electro-sterilization with antiseptic ions in cases of extensive necrosis of the jaws resulting from exanthematous fevers, phosphorous, mercury or extensive trauma, such as are so frequently caused by bullet wounds in this great European war, but bacteria infection is always present in these cases and sepsis is the greatest difficulty in their treatment; it seems possible that surgical and other treatment would be greatly aided by the electro-sterilization of the septic areas.

Marginal Gingivitis.—A form of gingivitis is sometimes met with which is exceedingly painful and difficult to deal with; the gingival border is red and inflamed around the necks of the teeth, particularly on the external surface for a limited distance from the necks of the teeth, but uniformly about the entire denture. The dental papillæ between the teeth break down and slough on the surface, but there is little or no hypertrophy, nor is the inflammation of a proliferative character. The condition is found in adults, and is sometimes associated with digestive disturbances, due to high living and free use of wines. The condition resembles the acutely painful condition of the gums in ordinary stomatitis without the general congestion of the mucus membrane, etc. The patient complains of constant pain in the gums, which is increased by taking solid food.

In these cases the author has found useful and soothing the application of 10 per cent. solution of argyrol on a pellet of cotton-wool placed about the necks of three or four teeth at a time, a platinum electrode laid flat on this and 0.5 to 3 ma. current (according to how the current is tolerated) from the positive pole for a few minutes. This repeated about all the affected parts relieves the pain and a few such treatments usually gives great relief and cures the condition. Other local treatment consists in cleansing the teeth and a mouth-wash should be prescribed, as well as a light diet and forbidding the use of stimulants.

Argyrol is a colloid substance (a silver preparation made with nucleinic acid) which is not supposed to ionize, but with the current it certainly has a soothing and beneficial effect on sloughing gums. The author has used it in bad cases of stomatitis, which had refused to yield to many other drugs applied by painting the gums or mouth washes, and has effected complete cures with nothing else but argyrol applied with the current.

CHAPTER XIV.

TREATMENT OF PYORRHEA ALVEOLARIS.

Periodontal Disease—Incipient Infection of the Gingival Trough—Septic Infection of Gingival Trough without Suppuration—Septic Infection of Periodontal Membrane—Acute Septic Infection of Gums and Periodontal Membrane—Chronic Septic Periodontal Disease.

Periodontal Disease.—This includes a variety of acute and chronic forms of periodontal affections which are not pyorrhea alveolaris in the incipient stages, but which invariably lead to suppuration of the periodontal membrane, when it is correctly termed pyorrhea alveolaris. Definition of terms, pathology, etiology, or bacteriology are not the phases of the disease with which this work is intended to deal; it is the therapeutic aspect which will be chronicled from an electrolytic stand-point. It will be necessary to classify different stages of periodontal disease, for which particular kinds of treatment are advocated, but before doing so the author desires to emphasize the utter futility of trying to cure pyorrhea alveolaris by ionic medication without recognizing and removing certain etiological factors, which are always present. Electro-sterilization is intended to deal with pathogenic microörganisms which are a constant factor; this it does most effectively when other factors are taken into account and properly dealt with; these may be summed up under the heading of *local irritants*. Irritants in the form of calcareous deposits or any form of foreign matter on the surfaces of the teeth must be completely removed, and the teeth polished, not only above the gum margin but also the roots which are denuded of periodontal attachment, rendering the mouth in a perfect hygienic state.

Irritants in the form of ledges, rough or overhanging

fillings at the cervical margin, imperfect crowns, ill-fitting mechanical appliances, anything that irritates and inflames the gingival margins must be removed.

Irritants in the form of faulty occlusion and undue stress must be rectified; these, often most subtle and difficult to recognize, are nevertheless of greatest importance and demand correction if any form of treatment is to succeed.

The fulfilment of these conditions in the treatment of the disease is often a difficult matter, requiring utmost skill and patience, but, if faithfully carried out, the supplementing of electro-sterilization of the tissues enhances greatly the lasting effect of treatment and shortens the time in which a cure can be accomplished.

There are many who claim good results in the treatment of periodontal disease from perfect instrumentation, hygienic methods and attention to the existing etiological factors, but ignore or else deal lightly with the contingent of existing pathogenic microörganisms in the weakened tissues; in the hands of these ionic medication would be invaluable in promoting a lasting cure of the disease.

There are many who pass through a long life of practice without ever mastering the details of scaling calcareous deposits from the roots of teeth. This failure of one of the most essential principles in the treatment of periodontal disease frustrates every other attempt to cure it. Some are convinced that the disease is incurable, and are content with vague ideas of "constitutional causes" or "rarefying osteitis," as unsurmountable difficulties, and at the same time ignore the possibility of local irritation from calcareous deposits as an etiological factor of great importance, and rely on the forceps as the only real cure for pyorrhea alveolaris.

For convenience of description the different phases of periodontal disease are here classified as follows:

1. Incipient infection of the gingival "trough" or space.
2. Septic infection of the gingival trough without suppuration.
3. Chronic septic infection of the periodontal membrane without visible suppuration—"dry pyorrhea."

4. Acute septic infection of the gums and periodontal membrane without visible suppuration.

5. Chronic septic periodontal disease with pus.

1. Treatment of Incipient Infection of the Gingival Trough.—Special reference is here made to the gingival trough or space because it is the starting-point of general chronic alveolar pyorrhea. This space is a normal one, formed by the gum margin as it rests on the surface of the tooth, the periodontal membrane forming the floor of the space (see Fig. 147). In a very large percentage of healthy mouths, if this space be examined it will be found to contain

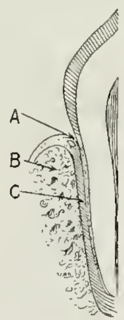


Fig. 147.—*A*, gingival trough; *B*, alveolus: *C*, periodontal membrane.

some form of foreign matter, rarely, if ever, is it perfectly free from deposits of salivary calculus or food débris in a state of stagnation and decomposition.

Incipient infection of the gingival trough may begin at a very early age in childhood, dependent entirely on the hygienic habits, environment, diet, abnormalities of the nasal cavity, etc., but not on the age. Abnormal appearance of the gingival margin in children is generally a sign of irritation from some cause, but in adults where the mouth is kept in a fairly hygienic state, it will be found almost invariably that if a flat platinum probe be passed into the gingival trough, parallel with the long axis of the teeth, an irregularity of

surface or roughness can be detected by the sense of touch as the probe passes over the surfaces.

The gingival trough is always infected by mouth bacteria, which are harmless in healthy tissue, but irritation from foreign matter causes inflammation which is accompanied by infection of pathogenic microörganisms. Just at what stage this infection occurs is impossible to demark, but it is probably before any outward signs are visible. In order to *prevent* the development of periodontal disease it is advisable to cleanse the gingival trough by removing any trace of salivary calculus or stagnant food and to polish the tooth surfaces. The gums should then be treated by electro-sterilization with iodine ions. A platinum electrode should be wrapped with a few shreds of cotton-wool, saturated with 10 per cent. aqueous solution of tincture of iodine. This should be passed into the gingival trough and the current gradually turned on from the negative pole, the patient holding the positive electrode; 2 ma. current should be passed while the operator slowly and gradually moves the electrode in perfect contact around the necks of the teeth wiping out the trough with the cotton and solution. This will sterilize the tissue, which may be in the incipient stages of infection with pus-producing varieties of microörganisms. The gingival margins treated in this manner assume a tough and healthy appearance, clinging close to the necks of the teeth, and are more able to resist subsequent infection. The gingival trough once enlarged by the entrance of foreign matter is liable to recurrence of the trouble, and should be treated whenever foreign matter is detected. Keeping this space clean and healthy is the only means of *preventing* the development of periodontal disease, and is worthy of every attention, especially when there is reason to suspect a tendency to disease.

Mr. Hopewell-Smith in referring to the "Normal arrangement of osseous and fibrous tissues"[1] says: "It is the writer's belief that not only do all human teeth possess spaces around

[1] Dental Cosmos, liii, p. 981.

their necks, which may become potential cavities for the retention of microörganisms, but that if great care be exercised in the laboratory manipulations, it will be found that microörganisms can always be demonstrated in ordinary circumstances, occupying the site thus produced. It is when they are of the pus-producing varieties that pyorrhea alveolaris is established." This being the case, as undoubtedly it is, the method of sterilizing the mucoperiodontal tissues referred to must effectively prevent the beginning of pyorrhea alveolaris. Sets of teeth which are perfect and gums about them which may appear healthy are often in the incipient stages of periodontal disease, and should be examined and treated when foreign matter is present in the gingival trough. Endless misery might often be averted by this precaution.

2. Septic Infection of the Gingival Trough without Suppuration.—This is the second stage of local septic periodontal disease, in which inflammation of the gum tissue is discernible; a certain amount of congestion is present, the gingival fold is loosened from the neck of affected teeth and the trough slightly deepened, making it easy to enter the space from which bleeding readily occurs from the inner surface. The gingival trough at this stage is found to contain food débris and salivary calculus, often extending from the enamel surfaces of the teeth which have been badly kept. In well-kept teeth nodules of hard, dark calculus, which is most tenacious and difficult to remove, may be the only irritant in the trough. Inflammation has been caused by the presence of foreign substances in contact with the delicate epithelial lining of the gingival fold, and the tissues, in this state for a considerable time, become the seat of infection by pathogenic microörganisms. A process of breaking down of the gingival fold, the alveolar bone (see Fig. 148) and surface fibers of periodontal membrane is established, which will proceed to general chronic periodontal disease if not checked. Often the deposit is rough and sharp and chiefly to be found in the approximal spaces, causing congestion and the bleeding of the interdental papillæ. Treatment consists in

thorough instrumentation, removing every particle of foreign substance and polishing the necks of the teeth. Ionic medication indicated consists in passing zinc ions into the gingival trough. A zinc electrode, spear-shaped, of large enough size to readily enter the trough should be wound at the point with a little cotton-wool, saturated with 3 per cent. zinc chloride solution and passed into the space; the current trom the positive pole should then be turned on gradually, fhe patient holding the negative electrode. The teeth should be kept free from moisture from the mouth, the electrode

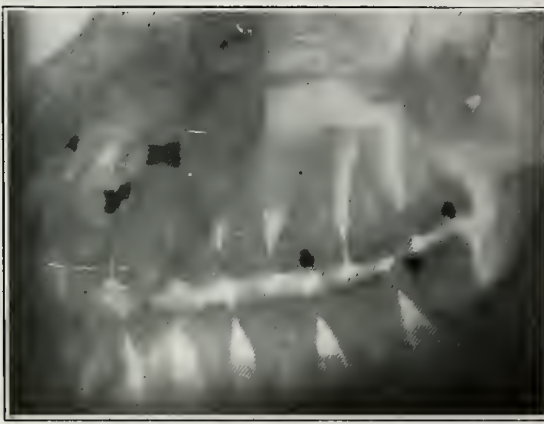


Fig. 148.—Progressing periodontal disease.

should be very slowly moved around the necks of the teeth, which, if not sensitive, will tolerate 2 or 3 ma. current. The trough is in this manner sterilized with zinc ions which migrate readily even with very much less current strength. The time required to go round each tooth should occupy on an average about a minute, some places requiring a longer time, others less affected, a shorter. Discretion must be used in the matter of time required to sterilize soft tissues. Ions are conductors of current and move instantaneously, the time and current strength work in direct ratio to each

other to produce depth of penetration. In mucous tissue (2 ma. current with a small area electrode) the current density is very great, and the dose of ions provided in one minute over a small area of a gingival border must be considerable.

One treatment will often be sufficient if all foreign matter has been completely removed, and the teeth polished, but the patient should be seen in three or four days, and if this condition has not been fulfilled, redness and congestion will be present wherever any irritant is lurking. This should be removed, and the affected part treated as before. The gums by this treatment will resume a normal appearance, and contract about the necks of the teeth, restoring nature's barrier to the introduction of food débris into the gingival trough, and averting subsequent periodontal disease.

Fig. 149

Fig. 150

3. Chronic Septic Infection of the Periodontal Membrane without Visible Suppuration—"Dry Pyorrhea."—This phase of periodontal disease is most subtle and is rarely recognized in the incipient stages. The irritation set up in the gums by the presence of foreign matter and bacteria infection is confined to the inner surface of the gingival fold, extending to the dental ligament, which it destroys by a slow process, the conical border of alveolar bone is affected, and gradually absorbs by a process of rarefying osteitis (see Figs. 149 and 150), the superficial fibers of periodontal membrane are

destroyed to a considerable depth before the necks of the teeth become exposed. The gums are thinned and become a mere layer of tissue, which clings closely to the necks of the teeth; the interdental papillæ disappear, and spaces appear between the teeth over the alveolar bone, which has absorbed at the margins; the teeth are usually quite firm. It occurs in well-kept mouths and is often attributed by dentists to overbrushing or associated with gouty or rheumatic diathesis, being termed by some authors "gouty periodontitis which is rarely recognized before the age of thirty." The author considers this "gouty diathesis" a coincidence, which has little to do with the direct cause and progress of the disease, except for the augmenting of an irritant in the form of minute granular deposits of hard calculus, which adhere firmly to the roots of the teeth, and *in the first instance* starts the inflammatory action of a subtle and slowly progressive character. A flat probe passed into the gingival trough between the thin, taut layer of tissue and the roots of teeth will reveal considerable loss of periodontal attachment, and always a layer of calcareous deposit, sometimes of dark, hard nodules, but more often of a finely granular nature, most difficult to detect. This form of the disease is difficult to deal with. If recognized in the early stages the gums are not wasted, and the removal of the calculus is not as difficult as later when a thin stretched layer of tissue resists the proper use of scalers and the polishing process. Treatment consists in removal of every particle of irritant, and sterilization of the infected gums and periodontal tissue. Electro-sterilization is often painful, owing to the sensitive nature of the roots of the teeth and the thinness of the gums. A thin platinum or zinc electrode should be wrapped with a few shreds of cotton-wool, saturated with 3 per cent. zinc chloride and passed into the gingival trough, the current from the positive pole should be slowly turned on, the patient holding the negative electrode. If the teeth are sensitive 0.5 ma. current may be all that will be tolerated in the incisor region, but the molar region will usually admit of 2 or 3 ma. The electrode should be slowly moved parallel with the long axis of the teeth around the necks, with the object of steriliz-

ing the gingival trough. The tissue overlying the roots of the teeth is very thin, and the time required to sterilize the neck of a tooth must be in ratio to the current strength, varying from half a minute to one minute.

The number of treatments required depends upon the severity of the case, and the current strength available. Three the first week, two the second, and once a week after until every sign of inflammation about the gingivus has disappeared, gives some idea of the course that should be pursued in combating this affection of the gums. Fetid odor is often complained of by patients and is sometimes the only discomfort. Until this disappears entirely the treatment should be vigorously continued every second day, after which the intervals should be extended to every third day, and later to once a week. Fetor is usually due to disease in the molar region, and here a larger current strength is generally tolerated and should be used, in order to carry out sterilization. The daily use of an antiseptic lotion on the brush should be insisted on. The restoration of lost bone and gum tissue cannot be looked for in these cases; the arresting of the progress of the disease is all that can be accomplished, and this can only be effected by stopping infection of pathogenic microörganisms, which have taken hold of the weakened tissues. One case of many the author has successfully treated may be mentioned in support of the value of zinc medication in this phase of the disease. Lady R. consulted me eight years ago for "receding gums," The necks of the maxillary incisors and cuspids were exposed and the premolars and molars showed signs of the trouble; the teeth were highly sensitive to thermal changes and also to electric current. Subgingival calculus of a hard, dark, granular type was found beneath the gum margin on every tooth, and principally in the interspaces, the dental papillæ had disappeared from the interspaces of the superior incisors. The teeth were free from caries and beautifully white, even, and well kept. She informed me that her dentist had cleaned her teeth four times a year, still the receding gums was progressing. The gingival trough was treated (after deposits

had been removed) with zinc and iodine ions. At the first course of treatment, which extended over six weeks at intervals of three and four days, the current strength of 0.5 to 1 ma. was all that could be used on the anterior teeth on account of sensitiveness of the necks of the teeth. One treatment with zinc ions was given at intervals of four months for a year after the first course, and the gingival trough examined for deposits. Since then the patient has been seen twice a year, and when any irritant was discovered in the gingival trough it was sterilized as before. The sensitiveness has gradually disappeared, and at a recent sitting it was possible to pass 4 ma. current about the interspaces of the superior incisors, where previously it was painful to 0.5 ma. Zinc ions act slowly but surely as an obtundant to sensitive dentine. In this case the "dry pyorrhea" has been completely checked, and the author does not think that cleaning alone would have been effective; the electro-sterilization of the gingival trough is a necessary adjunct to effect a permanent cure of this slowly progressing septic destruction of the periodontal tissue and alveolar bone.

4. Acute Septic Infection of the Gums and Periodontal Membrane without Visible Pus.—This stage of the disease is marked by congestion of the gums, the papillæ are enlarged and heaped up between the teeth in loose tags, which bleed freely when touched; the gingival trough is much deepened by the loss of dental ligament, inflammation of the gingivus is general. This stage is a continuation of the second stage described in this series, and is marked by greater stagnation areas and greater accumulations of foreign substances, débris of soft food in stages of decomposition and quantities of calcareous deposits extending into the gingival trough. In young subjects this condition is often associated with lack of proper masticating function, mouth-breathing and imperfect brushing. In adults the only cause is irritants in the gingival trough—tartar and food débris. The gums become tender, bleed freely and proper brushing is impossible. This may be the condition extending to the entire denture without any deep pockets yet formed, or may be the con-

dition of a certain area, other parts being less affected, or may be the area leading up to a much worse area of infection, which has succumbed to the ravages of chronic pyorrhea alveolaris. The clinical appearance varies considerably, but is marked by considerable inflammation *without visible pus.*

Treatment consists in removing the irritant cause; this excites free bleeding and is painful, making it impracticable to carry out electro-sterilization at first, but the inflammation subsides quickly after the gingival trough is cleansed and ionic medication with zinc or silver ions soon arrests the inflammatory progress. Electro-sterilization should be carried out with 3 per cent. zinc chloride, or 2 per cent. silver nitrate in cases where there is sloughing of the borders of the interdental papillæ. A platinum or zinc electrode, wound with a few shreds of cotton-wool and saturated with the solution, should be used to slowly wipe out the gingival trough with 2 or 3 ma. current, keeping the electrode in good contact with the tissues while moving it, and frequently turning off the current to replace fresh wool and more solution when bleeding of the tissues interferes. Two or three treatments with zinc ions at intervals of three days will often be sufficient to reduce the inflammation, and produce a healthy reaction of the gums.

Polishing the surface of the teeth after removal of salivary calculus is necessary, and as soon as brushing with a stiff brush is possible the patient should be instructed in a useful daily hygiene with antiseptic lotion on the brush. The ionic medication should be continued until every sign of inflammation subsides, which will not occur if any trace of irritant is left in the gingival trough or on the surfaces of the teeth in contact with the gum margins. Patients should be warned that this attack of gingivitis is the forerunner of pyorrhea alveolaris, and with deepened gingival trough and weakened alveolar border recurrence is very liable to occur if strict attention is not paid to daily hygiene and gum massage with a stiff brush.

The eradication of pathogenic organisms in the tissues is

accomplished by the electro-sterilization and so long as irritation and inflammation of the tissues are prevented the mouth organisms can have no influence on the tissues.

5. Chronic Septic Periodontal Disease with Pus.—This stage of the disease is simply a continuation of those already described, there is *never* a starting-point of pyorrhea alveolaris below a healthy gingival border, and it is a matter of impossibility for pus-yielding pockets about teeth to be established without the incipient stages of periodontal disease being passed. Special attention has been drawn to the early stages of periodontal disease with the express purpose of saddling the responsibility of occurrence of pyorrhea on those who neglect the proper care of the gingival trough for their patients. Endless misery could have been saved to a host of people now suffering from pyorrhea if their dentist had but recognized and treated the incipient stages of periodontal disease and warned those people of the importance of proper hygienic preventive methods. Many people, of course, have themselves only to blame from neglect or ignorance. From whatever cause, unfortunately, we are often called upon to treat the disease in the stage when it has progressed considerably; the periodontal membrane has been destroyed to a considerable depth, pus-yielding pockets are established and rarefying osteitis is in progress, with septic infection of the hard and soft tissues. The general symptoms and clinical appearance of the disease are well known and description is unnecessary here.

Treatment by ionic medication is intended to deal with one etiological factor, which, at this advanced stage, is a great menace to the surgical side of the work. Pathogenic micro-organisms lurk in the tissues, enter the alveolar bone and are readily absorbed into the general circulation. It is to destroy deep-seated bacteria, that electrolytic sterilization is specially adaptable.

Clinical proof of the *antiseptic nature* of electrolytic ions of zinc, copper, silver, etc., has been recorded by the highest authorities (see p. 244) and the author has experimentally demonstrated that the *depth of penetration* of dissociated ions

in the soft tissues and alveolar bone is very considerable with a small current strength in a very short time (see p. 209). On these two requirements hinge the great usefulness of this method of treating pyorrhea. In treating advanced cases there are always many etiological faetors to be taken into account, in order that success may be assured in overcoming the one for which electro-sterilization is required.

Radiographs of roots of the teeth should first be obtained. This is best done in sections of four teeth at a time, the film inside the mouth. Condition of the bone, depth of pockets, calcareous deposits, faulty fillings and crowns are thus exposed. The radiographs should be referred to at intervals while treating the various parts of the mouth. Figs. 151

Fig. 151

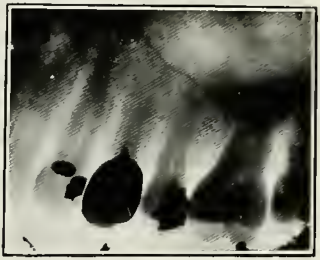


Fig. 152

and 152 show upper and lower teeth of a case treated in June, 1913. The patient had received peremptory orders from her medical adviser to have every tooth extracted. This advice had been given on account of the toxæmic effect of pus from the mouth, causing malaise and rheumatism in the shoulder- and knee-joints, by which the patient was nearly crippled. Her dentist had agreed that extraction was the only course to follow.

Treatment consisted in removing quantities of hard subgingival tartar, thorough instrumentation and perfeet polishing of the necks and roots of teeth. This was accomplished only by repeatedly searching under the gums for particles, which, owing to the hard, tenacious nature of the deposit,

were difficult to eradicate completely. At each treatment, after scaling and polishing for half an hour, ionization was carried out for half an hour, the patient having the negative electrode, a zinc positive electrode was wound with a few shreds of cotton-wool and saturated with a solution of 3 per cent. zinc chloride. This was passed to the bottom of the pockets between the teeth and 3 to 5 ma. current passed for half a minute to two minutes. The gingival trough was ionized by slowly moving the electrode out of the deeper pockets around the necks of the teeth, every part of the tissues comprising the trough was treated. Treatment was carried out every second day, most attention being given to pockets which were deepest, and from which pus could be expressed. Four crowns and a faulty filling shown in Fig. 152

Fig. 153

and 153 were removed, these being the chief cause of sepsis in the molar region. In every instance after the removal of the irritant cause and ionization, pus ceased and condition improved. Treatment was kept up until the gingival trough was perfectly healthy; and bleeding, which at first was excessive, completely ceased even when instruments were forcibly passed under the contracted gingival border.

The case, which was undertaken on June 10, 1913, required eight treatments that month, during which time malaise completely disappeared and rheumatism greatly improved. Five treatments were given up to July 24, on which date every symptom of pyorrhea had disappeared and also the rheumatism. The patient was instructed in a useful method of daily hygiene and a benzoic acid wash prescribed as follows:

℞—Thymol		gr. iij
Benzoic acid		ʒss
Ol. cinnam.		♏x
Acid carbolic		♏xxx
Otto Rosæ		♏xv
Alcohol	ad	℥iv—M

Sig.—A few drops on the wet brush twice a day.

The management of cases after treatment is of vital importance. This one was seen once a month for three months, and wherever the slightest redness of the gingival border was detected treatment was repeated, and the patient's attention was drawn to the cause, which was invariably neglect to completely remove lodgments of food. During the next year the teeth were thoroughly polished every four months and since every six months. There has been no recurrence of pyorrhea or rheumatism for four years. Should any particular part become affected in future one or two treatments will be all that is necessary to restore the parts. The case is typical of what can be done by electro-sterilization of pyorrhea to bring about what can be rightly claimed to be a complete cure of the disease.

A viscid, glairy mucus is often present which coats the teeth and adheres closely to the surfaces. This should be systematically removed at each treatment by brushes on the engine with powdered pumice made into a paste with an antiseptic mouth wash and ipecacuanha tincture, equal parts, leaving all the teeth highly polished after each sitting. This mucus coating will generally disappear when the disease is cured, but occasionally the mucous glands about the mouth become infected with pyogenic microörganisms, and exude a sticky mucus approaching the appearance of pus, which the patient may mistake for pus from the gingivus. Should this occur, the surface of the gums and mucous membrane on the buccal and labial aspect should be treated by placing a layer of cotton-wool saturated with 2 per cent. zinc chloride on the gums, pressing it into place with a flat zinc electrode, and passing 5 to 10 ma. current for two to four minutes on a surface of about an inch long, repeating this all around the mouth until the entire gum surface has been ionized. Two

or three such treatments will sterilize the tissues and change the secretion to normal consistency.

Faulty occlusion and undue stress on one or more teeth will keep up an irritation to the periodontal tissue and bone, which will defy all treatment. This condition must be corrected, or no amount of ionization will avail. It is desirable to ligature loose teeth together, holding them firmly in the sockets until all inflammation is reduced and the hard and soft tissues being thoroughly sterilized, a fresh deposit of alveolar bone is formed about the roots and the teeth become firm. All necessary instrumentation and polishing should be done before ligaturing, and ligature wire should be so placed that it cannot slip down on the gums, and the patient

Fig. 154

must be instructed how to keep the interspaces clean. In cases of great loss of bony attachment permanent splints fixed to the lingual surface of the incisor teeth are useful in retaining the teeth and rendering them functional for a number of years. Teeth which have taken up abnormal positions—been displaced by the disease affecting one surface only, like the approximal surface of incisors—should, after instrumentation, be treated by electro-sterilization and replaced in normal position and retained there. Splints are in those cases a great advantage. Fig. 154 shows a case of the kind treated over ten years ago, which has been cured by this means and the spread of the disease completely checked.

The clinical aspect of the gingival border and alveolus

after treatment and general prognosis must now be referred to. After thorough instrumentation, polishing of the teeth and treatment with electro-sterilization, invariably improvement in the general aspect of the gums is noticeable, but experience shows that this does not constitute a cure, often a refractory pocket here and there may continue to exude pus, or pus may be expressed if great care is taken to find it. This is nearly always a sign that a special cause is at work, either a particle of calculus left beneath the gums, undue stress, or some irritant cause, which must be removed and ionization vigorously continued with an increase of the time and current strength to that particular part. Even after all signs of discharge have disappeared, the contraction of the gum tissue on the necks of teeth must be noted, and no hope of permanent results can be expected if the gingival trough remains wide open to receive food débris at every meal. Ionization must be continued until it is fair to expect that the reasonable coöperation of the patient is sufficient to prevent stagnation in the gingival trough. This is always possible if in the first instance proper judgment has been exercised in the removal of such teeth as are so hopelessly involved that treatment will be useless. This does not mean that all loose teeth or teeth with deep pocket should be extracted, these can often be restored to perfect health. The regeneration of bone about the sockets of pyorrhea teeth is an established fact, although seriously doubted by some eminent authorities. Mr. Hopewell-Smith[1] in his concluding notes on "Pathohistology" of pyorrhea alveolaris, referring to the treatment of the disease says: "The hopelessness of retaining the teeth and of building up bone which has been lost by absorption or the recalcification of decalcified foundations must be apparent. The treatment, at best, can only be palliative, and, unfortunately, only directed to a prevention of further destruction, and not the rehabilitation or reconstruction of parts absolutely forever destroyed." The writer is convinced that alveolar bone seriously affected by

[1] Dental Cosmos, liii, 991.

chronic pyorrhea is capable of reformation about the sockets of loosened teeth. Instances are constantly seen where teeth are exceedingly loose, moving freely in enlarged sockets (as is always the case in faulty occlusion or undue stress), but when, under treatment, all irritant causes are removed and the septic infection dealt with, the rarefied bone recalcifies and the sockets reform about the roots, leaving them in a firm, healthy condition. Proof is also furnished by radiographs taken before and after treatment (Figs. 158 and 159). It is not useless or hopeless to retain a set of teeth, which is badly affected by pyorrhea, in a functional state for a space of fourteen years or even six years, provided the septic infection can be kept away, even if it is necessary to treat the teeth two or three times a year in order to obtain such results.

Fig. 155.—Case C, model 1 before treatment, and 2 fourteen years later.

The Case C, reported on p. 240, is one in which extensive pyorrhea with constitutional symptoms accompanying it existed, the pockets on the palatal aspect of the incisors

extended nearly to the apices, every symptom of chronic pyorrhea existed. When the teeth were retracted to the position of the diagram on p. 241 they were so loose that they could be moved forward a distance of about 5 mm. without

FIG. 156.—Radiograph January 29, 1907.

touching a bony socket. The bone has reformed in those empty sockets, and not only reformed but grown thicker on the labial aspect of the alveolus than is normal, as shown by the photograph of the models taken before treatment and fourteen years later (Fig. 155). The recurrence of

FIG. 157.—Radiograph May 30, 1912.

pyorrhea has not taken place, no teeth have been lost and the once diseased denture has been functional for over fourteen years.

On January 29, 1907, the accompanying radiograph was

taken of a patient suffering from every symptom of pyorrhea including constitutional disorders. This radiograph was sent to Mr. C. Clark, of London, with the patient on May 30, 1912, with a request to produce a picture of the same parts. The result will be seen in the radiograph, Fig. 157. It will be seen that the alveolus has changed considerably in five and one-half years; between the second premolar and the cuspid carrying a bridge the bone has quite a different contour, it is a higher level, there is more alveolar process about the molar roots, and the posterior boundary of the last molar has a growth of alveolus resembling a molar, which is

Fig. 158.—Radiograph December 7, 1906.

new bone. Allowing for a slight difference of angles at which the radiographs were taken, there is still a marked difference in the appearance of the bone, the first shows marked decalcification and morbid changes, the second shows a reformation of bone about the roots of the teeth. The clinical changes are no less marked, the pyorrhea has entirely disappeared, the gums are healthy and the teeth firm. The pyorrhea was treated with zinc ions.

Another example is shown in Fig. 158; radiograph taken on December 7, 1906, which shows pyorrhea started about the superior incisors; this case was treated with zinc ions. The

radiograph taken on June 6, 1912, shows that no change has taken place in the bone surrounding the roots of the teeth, except possibly a denser calcification. This appear-

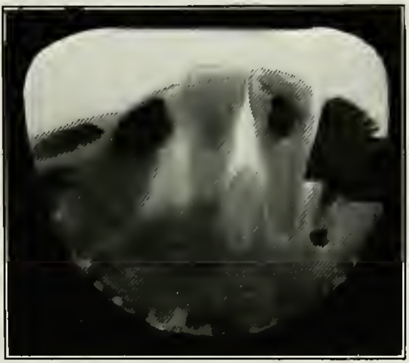


Fig. 159.—Radiograph June 6, 1912.

ance, however, may be due to the difference in length of time in exposure when taking the radiograph, but the loss of bone was no more than it was six years previously. The progress of the pyorrhea has been checked by a few treat-

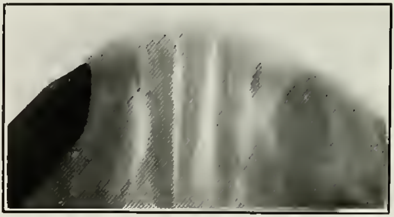


Fig. 160.—Radiograph January 29, 1907.

ments of zinc ionization and subsequent half-yearly treatments which consisted chiefly in thoroughly cleaning the teeth.

The next radiograph taken January 29, 1907, shows a bad case which has been cured, and the discharge has not returned

since treatment five and one-half years ago, although it has required constant attention to keep it from relapse, owing to the faulty articulation and constant irritation thereby. It will be seen that the teeth in the second radiograph (taken May 30, 1912) have been ground on the occluding surfaces to correct this. The teeth are functional and not very loose, as would be expected by the appearance of these radiographs.

Fig. 161.—Radiograph May 30, 1912.

It makes the greatest difference to people affected with pyorrhea to this extent if by treatment they are able to retain their teeth for years, and are saved the wearing of plates, which usually act as irritants and lead to the loss of the entire denture from progressive periodontal disease.

A healthy fibrous tissue forms about the teeth in these cases which holds them firmly in position, and if kept from bacterial infection (as they can be by ionic medication) they are retained and are functional.

It must not be thought that the disease is curable at any stage by simply ionizing the periodontal tissue and alveolus. There are many conditions which arise that defy all treatment. It is difficult to formulate any rule to classify the teeth which should not be treated by any other means than by extraction.

In determining the necessity for extraction of teeth, judgment should be exercised at the outset, and circumstances attending each individual case should be carefully weighed.

If constitutional disorders of any kind accompany the local symptoms, and if medical opinion points to the supply of small doses of toxins being the cause of the constitutional disturbances, it would be unwise to attempt to retain such teeth as cannot be *kept* in a perfectly aseptic condition by the patient after treatment, such as multirooted teeth with pockets that extend under the bifurcations, or teeth with pockets extending to the apices destroying the pulp, or teeth which with the adjoining one form V-shaped spaces, wholly inaccessible by the patient; whenever proper daily hygienic methods are impossible for the patient, individual teeth which are the cause of keeping up a septic foci should be removed at the commencement of the treatment.

The author has never seen a case in which it was necessary to extract a whole set of teeth to relieve constitutional disturbances from toxemia. If the toxins from pyorrhea are the potential source of the trouble, it is invariably the case that the periodontal disease is not so general as to make it impossible to cure the least affected teeth, and the removal of those which cannot be made aseptic and kept so will relieve the constitutional disturbances, at the same time retaining organs of mastication, which are just as vital for the health of the patient as the radical removal of the source of toxins.

Teeth which have to be extracted or been lost previously to the case coming under treatment should be replaced by some mechanical means which will ensure the restoration of balance of the entire denture, and relieve undue stress on any particular location, special care being exercised not to furnish an irritant to the parts on which this artificial restoration is dependent for its attachments.

CHAPTER XV.

ELECTRICITY FOR ANESTHESIA, FOR BLEACHING, AND FOR NEURALGIA.

Anesthesia of Sensitive Dentine—For Immediate Extirpation—Anesthesia of Gums and Alveolus—Electric Tooth Bleaching—Bleaching with Chlorinated Lime—Bleaching with Hydrogen Dioxide—Neuralgia.

ANESTHETIC APPLIED BY ELECTRIC CURRENT.

Anesthesia of Sensitive Dentine.—The anesthetic effect of cocaine on sensitive dentine when applied by the electric current is well known. In America the interest of the dental profession was attracted to this subject by W. J. Morton in 1896, who attributed the effects to cataphoresis. A mass of literature has since appeared from time to time setting forth the advantages and disadvantages of anesthesia of dentine by electrical application of cocaine.

The use of the current for this purpose has often been brought into disrepute by the lack of knowledge of general electro-therapeutics. Cataphoresis has been the only effect thought of, and it has not been realized that cocaine ions penetrate dentine with a very low current strength, and that if the electrical application of the drug is pressed too far complete anesthesia of the pulp takes place, when it may be only desired to benumb the sensitive surface of the dentine.

As has been pointed out already in this work the effect of the electric current on cocaine is not an electro-osmotic effect in the sense of propelling the solution of cocaine *en masse* into the dentinal tubuli by cataphoresis, but it is ionic in the sense that the particles of cocaine are dissociated in the solution containing them, and being electrically charged are conveyed by conduction into the organic

structure of the dentine on whieh it has an anesthetic effect. The depth of penetration of cocaine ions will depend on the organic structure of the tooth and the current strength which is used.

Cocaine ions penetrate the superficial layer of sensitive dentine with a current strength of only 0.5 ma. and produce anesthesia. With a stronger current the effect is more rapid and the penetration is deeper. Failure to produce the anesthetic effect in a few minutes is usually due to faulty technic. If the electrode is placed on a surface of dentine so that the current is only passed from a small area (see Fig. 162), the area in contact with the metallic

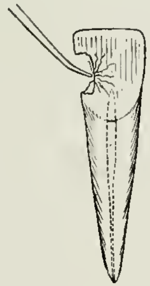


FIG. 162.—Imperfect technic.

conductor only will be affected by the passing of cocaine ions, and penetration will be greatest at the point of eontact. In order to obtain perfect anesthesia of the whole surface which it is desired to affeet, the eleetrode should cover the whole area. This ensures the passing of ions into all the organic matter exposed to conduction of current, and the larger the area the less painful will the proeess be, as the density will be lessened by the increase of area of the electrode.

To anesthetize dentine in the eavity of a tooth, a 5 to 10 per cent. aqueous solution of codraline, novocain, eoeaine, or any of the eocaine preparations now in use, should be

placed into the cavity on a pellet of cotton-wool and should be warmed to 99° F. On this should be fitted a piece of platinum foil sufficiently large to cover the whole area of the cavity and to this a platinum anode applied. The current should be turned on gradually until it is felt by the patient, when it should be allowed to pass for a minute, and increased until again felt. Except it is desired to anesthetize the pulp, current should never be raised to the strength of 4 ma., for should it be possible to pass this amount of current without pain the pulp will then be found to be anesthetized and can be removed without pain.

A point in technic which has already been insisted upon, but which may not have been especially noticed, is here again referred to, *i. e.*, when a voltaic cell battery is used it should never be of that kind which is provided with a "current collector" alone, if it has a current collector (that is, a switch with studs representing each cell of the battery) it should also have a finely graded rheostat of graphite or German silver wire with sliding contact, which permits of only a fraction of a volt increase of E. M. F. when the resistance is decreased by moving the shunt of the rheostat; the current strength will then be increased by a fraction of a milliampère, and no shock is possible with this gradual increase of current. If stud contact points are used alone, at contact with each stud the E. M. F. is increased by 1 volt in some batteries and by 1.5 volts in others, according to the voltage of the cells composing them. This means that the current strength is also abruptly increased as will be indicated by the milliampèremeter, according to the resistance in circuit. In soft tissues like periodontal tissue increase of 1 volt will sometimes increase the current strength considerably. In dentine, owing to the great resistance of that tissue, the increase might be only 0.1 ma., but the shock of sudden increase of E. M. F. is even more severe than in soft tissues.

It is undesirable to anesthetize a pulp except it is to be extirpated, for in some cases it dies subsequently, apparently from the effects.

The influence of the current upon pulps which have been

anesthetized is a debatable point. It has been pointed out by some authorities that the death of the pulp may ensue, by others that no ill effects take place. Dr. Louis Jack[1] states "in deep cavities nearing the pulp, the effect extends to that organ. The recurrence of sensitivity takes place within a few hours. No injury appears to follow." This may not always be the case. In some cases if anesthesia is pressed to the point that the pulp is anesthetized the subsequent death of the pulp takes place. There is a scientific electrical reason for expecting this result, which has been demonstrated by experiment and in practice. If a platinum electrode is placed in albumin and a current of 2 or 3 ma. passed, coagulation takes place about the electrode. The electro-positive effect on blood is also to coagulate it; this effect is obtained in the treatment of aneurysm by electrolysis. If the albuminous ingredient of the pulp be coagulated by the passing of the current, which would undoubtedly be the case if 4 or 5 ma. of current is passed, the effect would be stasis and death of the pulp in the majority of cases. The cocaine would be absorbed and taken into the general circulation, and is not an element of danger in this respect.

The opinion that coagulation of albumin is the effect accountable for the death of the pulp, when it occurs after cocaine anesthesia is simply one of conjecture yet to be proved.

Dr. Finzi[2] points out that when cocaine is driven into the skin with an electrode 3 x 3 cm. with a current strength of 10 to 15 ma. for ten minutes, anesthesia of the area treated, of a very transitory nature, is produced but is followed by *hyperesthesia* and *hyperemia*, which persists for days. If this effect is also produced on the pulp tissue it would be sufficient to cause death of the pulp. The epidermis being of very different vascular construction from pulp tissue, hyperesthesia and hyperemia may possibly be averted by vascular absorption, and death of the pulp avoided in many cases; still there is the liability, from one

[1] Text-book on Operative Dentistry (Kirk), p. 167.

[2] British Medical Journal, November 2, 1912.

cause or another, of death of the pulp to follow cocaine anesthesia by electrotherapy.

For Immediate Extirpation.—For immediate extirpation of the pulp of a sound tooth a small opening should be made through the enamel opposite the nearest point to the pulp. When sensitive dentine is reached the drill hole should be lined with a pellet of cotton-wool saturated with the anesthetic and to this applied a platinum electrode of about the diameter of the hole; 0.5 to 1 ma. current should then be passed from the positive pole for a few minutes, at the termination of that time it will be possible to drill deeper toward the pulp, and if still sensitive a similar application should be made, slowly increasing the current strength to 3 or 4 ma. This will ensure the possibility of opening the pulp chamber; then a further application for a minute will produce complete anesthesia of the pulp. The electrode in this operation should be pressed firmly into position and kept steadily there, so as not to vary the resistance which in dentine is considerable owing to the small amount of organic matter. The current should be turned off before removing the electrode.

The ordinary precaution of isolating the tooth and keeping away saliva by application of rubber dam is advisable, although it is not always necessary to apply the rubber dam. Excess of cocaine may produce toxic effects by leaking into the soft tissue about the necks of the teeth, or by the passing of ions into the circulation through the pulp itself. It is therefore advisable to use cocaine mixed with adrenalin chloride, or novocain.

The operation of stapling or splinting incisors in pyorrhea cases is greatly facilitated by this method of anesthetizing the dentine and pulp. It is often advisable to remove the pulp from pyorrhea teeth which are to be stapled. This can be readily done by exposing the dentine in proximity to the pulp in the position of the receptacle for the pins necessary to form the staple. Then the teeth can be anesthetized with codreline, using a current of 3 or 4 ma.

In cases of inflammation of an exposed pulp when pres-

sure anesthesia is often impossible, cocaine ions can be used to produce complete anesthesia. The conduction of current is the same in inflamed tissue as in healthy tissue, and ions migrate just as effectively in one as the other. When the pulp is exposed, a minimum of 0.2 ma. current may be all that can be tolerated, but ions are conducted even at this low current strength, and it will be found that after a minute or two of passing this current it is possible to increase the strength gradually until anesthesia ensues, when 3 or 4 ma. can be passed without discomfort.

Anesthesia of the Gums and Alveolus.—Anesthesia of the gums and alveolus for extraction can be successfully carried out by Dr. W. J. Morton's[1] method of applying a metallic-lined rubber cup electrode to both sides of the gums about the teeth, but this method is more difficult and less sure for this purpose than hypodermic injections as now generally practised.

ELECTROLYTIC TOOTH BLEACHING.

Discoloration of teeth due to chemical changes of the organic contents of the dentinal tubuli and also absorption by the tubuli of putrescent products of the dead pulp tissue provides one of the knotty problems which often taxes the skill of the careful and ingenious operator to the utmost. The subject of the chemistry of tooth discoloration has been ably expounded by Dr. E. C. Kirk,[2] who states that "the proteid elements of the pulp tissue are complex combinations of carbon, oxygen, hydrogen, nitrogen, sulphur, and phosphorus, which in the gradual breaking down of the process of putrefactive decomposition are split up finally into dioxide, water, ammonia, and hydrogen sulphide, with possibly the formation of traces of phosphatic salts." The principle of bleaching teeth should aim at the transfer of this chemical combination which causes the discoloration into a new combination by the addition of a fresh molecule,

[1] Cataphoresis, p. 222.
[2] Text-book of Operative Dentistry, p. 524.

which has the property of combining to form a compound of transparent or translucent appearance. This fresh molecule has long been known to be oxygen in its nascent state, the difficulty has been to procure it and to transmit it to the dentine tubuli containing discolored organic matter.

The most effective bleaching agents are calcium hypochloride or chlorinated lime, chlorinated soda, hydrogen dioxide, sodium dioxide, and pyrozone (an ethereal solution of H_2O_2). All these can be applied to the dentine of discolored teeth for their bleaching qualities more effectively *with* an electric current than without.

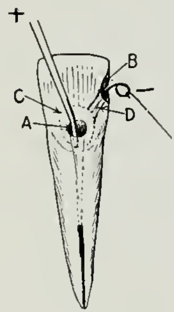


Fig. 163

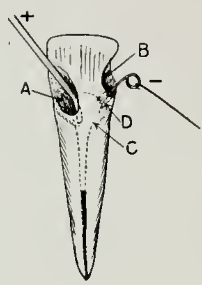


Fig. 164

Bleaching with Chlorinated Lime.—The general principles of technic in bleaching have been referred to under that heading in another part of this work and must be observed in the bleaching operation. The tooth must be prepared so that the two electrodes can be placed in it a little distance apart, but not separated by a portion of tooth structure; there should be liquid contact completing the circuit between the two poles. Fig. 163 is a diagram illustrating the electrical contact in a central incisor. *A* is the orifice of the opening into the pulp chamber which has been enlarged internally, as indicated by the dotted line *C*, into which is placed the + platinum electrode. *B* is a small drill hole in which is placed the − platinum electrode. *D* is a small opening made between

A and *B* to complete liquid contact and thereby reduce resistance effects. If the tooth is filled or decayed at an approximal surface this position should be utilized for introducing the second electrode (as shown in Fig. 164). Into the cavity, between the metallic conductors, should be placed a pellet of cotton-wool in the meshes of which has been incorporated a pasty mixture of chlorinated lime, and 2 per cent. sodium sulphate. The circuit should be established by gradually turning on the current until 5 ma. are measured on the milliampèremeter. By the electrolytic action nascent oxygen is eliminated at the positive pole and hydrogen and chlorine at the negative at the same time electrolysis of water takes place; H_2 molecules accumulate at the negative and O at the positive electrode. The chemical action which takes place by the passing of the current furnishes a large supply of nascent oxygen, chlorine, and hydrogen. The chlorine has a great affinity for hydrogen, with which it combines freely. The positively charged atoms $H_2 + Cl_2$ migrate to the negative pole, where they give up their charge of electricity to the electrode and unite to form 2HCl (hydrochloric acid), the negatively charged atom O migrates to the positive electrode, where it unloads its charge of electricity and O is eliminated. By this means a large quantity of oxygen is liberated in contact with the dentinal tubuli, the hydrogen which would unite with it to form water is utilized by the chlorine atom which leaves the nascent oxygen free to combine with organic matter in the tubuli of the dentine.

The action of these gases is hastened and increased by the evolution of heat which takes place during the passing of the current, the electrodes which should be thin platinum wire (0.5 mm. diameter respectively) become heated when the electro-motive force is about 20 volts, passing a current of about 5 ma. This heating effect can be increased by either diminishing the size of one electrode or by increasing the E. M. F. to 30 volts, passing 10 ma. By this means the tooth structure can be heated considerably, which assists the bleaching effect by increasing oxidation.

When bleaching is almost completed in the body of the

tooth a fresh supply of bleaching mixture should be placed in the tooth and the poles of the battery or switchboard reversed to complete the process about that part which formerly contained the negative electrode.

It will be noticed that during the bleaching operation by this method very little chlorine gas escapes, and the odor of chlorine is very faint. This is most likely due to the perfect union of $Cl_2 + H_2$ in the formation of $2HCl$; on the other hand, if a weak solution of sulphuric acid be used as the solution electrode with chlorinated lime, the pungent odor of chlorine gas is distinctly observed.

The canals of all teeth which are bleached with chlorinated lime should be previously sealed at their apices with gutta-percha. There are some precautions which should be observed when electrodes approximate each other so closely as here described. The wires should be properly insulated to prevent short circuiting; the solution electrode in the tooth should be replenished when necessary; if it become dry the resistance to current is much increased and heat is increased; one electrode should be made fast in the tooth by some mechanical contrivance, and should be made secure in posiition before attaching the conducting wire to it, if it is bent into a hook at the end as shown in the diagram (Fig. 164) the conducting wire can be readily attached; the operator should control the other electrode. After bleaching, all traces of the products of electrolysis and the bleaching agent should be removed, and the cavity wiped out with a solution of bicarbonate of soda or ammonia water.

Bleaching with Hydrogen Dioxide.—The bleaching with hydrogen dioxide, sodium dioxide, and pyrozone with the electric current are so similar in chemical action and effect that all can be described under the same heading.

In the case of sodium dioxide the migration of sodium ions (which are colorless) takes place at the + pole.

The method of applying both electrodes to the tooth already described is very effective in the use of H_2O_2 preparations. The current strength necessary to eliminate oxygen gas by this technic is reduced to a minimum and the resist-

ance of the body in circuit is eliminated; moreover, heat can be produced in the tooth without discomfort, which is a valuable auxiliary.

The H_2O_2 solution should be placed in the cavity on cotton-wool between the electrodes; on passing the current large quantities of gas is evolved at both electrodes; the *H* atoms migrate to the negative electrode and *O* to the positive. After operating with the current passing in one direction for five to eight minutes the poles should be reversed and current passed in the opposite direction for a similar time. In addition to liberating the very loosely combined oxygen atom in H_2O_2 solution, electrolysis of H_2O takes place, which supplies a further atom of nascent oxygen for action on organic matter in the dentine. In teeth of young subjects and recently discolored teeth the electrolytic bleaching action of the H_2O_2 is very rapid.

To facilitate electrical conduction in H_2O_2 preparations, the addition of 10 parts in 100 of 2 per cent. solution of sodium chloride or sulphate should be made; and in the case of ethereal solution of pyrozone the ether should be evaporated over a hot-water bath after adding a similar volume of 2 per cent. sodium sulphate.

NEURALGIA.

The term neuralgia is applied to a painful affection of either the course of a nerve or the area of its distributions. It is a condition of pain, which in the early stages may amount to mere flashes of pain, responding to some afferent impulse set up by an irritant in a remote part, but later a more lasting and severe pain results in consequence of continual irritation of the nerves responsible for the reflex action. Trifacial or trigeminal neuralgia which occurs in connection with the fifth nerve is constantly brought to our notice in its many phases. Diagnosis of the cause of facial neurálgia when the teeth are responsible for the irritation setting up this reflected pain in one of the facial segmented

areas is often difficult, but much is done by the dentist in his daily practice to arrest and relieve this form of pain. Nevertheless, obscure cases arise which defy the skill of the medical and dental professions, especially that form of neuralgia known as tic douloureux, which is not ordinary "referred neuralgia" but is often regarded as a diseased state of the Gasserian ganglion or a large branch of the fifth nerve.

Facial neuralgia is often caused from septic periodontitis and indirectly from the effects of this disease; the sensitive necks of teeth are exposed to the irritating influences of external agents which provide constant and more or less severe afferent stimuli to be sent out from the surfaces of the teeth, these sensitive surfaces are peripheral endings of the fifth nerve, which are exposed and convey painful impulses to the nerve trunk or Gasserian ganglion, resulting in reflex neuralgia. This form of reflected pain is exceedingly common among patients suffering from pyorrhea alveolaris, and the question of treating the disease should include the possibility of relieving this phase. It is often the case that acute neuralgia follows the operation of scaling the teeth, and many patients suffer from constant facial neuralgia who have so-called "dry pyorrhea."

The author has noticed with considerable satisfaction the remarkable effect on neuralgia which is caused from sensitive surfaces of teeth by their treatment with zinc ions. Many cases of persistent and long-standing neuralgia in the maxillary, temporal, frontotemporal, and mandibular areas have completely disappeared after treatment of pyorrhea with zinc ions and silver ions. In the treatment of these cases the application of the current at first causes neuralgic pains in the reflected area from which the patient generally suffers or corresponding to the area influenced by the particular teeth to which the current is applied, and it is often impossible to apply more than a very weak current, 0.5 or 1 ma., but when the pyorrhea is cured, at subsequent treatments it is the experience of the writer that the sensitiveness of the exposed necks of teeth has become less, the neuralgia is relieved, and teeth which were formerly painful when 1 ma.

current was applied are painless with 3 or 4 ma. The relief to neuralgia is usually very prompt, although the relief to the sensitive surface of the teeth is slow and may not be complete, so far as passing current is concerned, for several years, but the ultimate effect in this respect is sure and most noticeable from a clinical stand-point.

In the treatment of exposed roots of molars, especially in the palatal aspect of maxillary and approximal surfaces of mandibular molars, the application of silver ions from a weak aqueous solution of silver nitrate is very rapid in removing sensation from these surfaces and the effect is permanent.

The only construction that can be placed on the action of the ion in this respect is that it passes into the organic structure of the dentine and cementum by conduction, the penetration is into the protoplasm of the cell, where the effect of the ion is far more complete than if the drug were applied as tincture or liniment painted on the surface; the action in the latter case is only superficial and penetration at the best very imperfect. When we consider that by the electrolytic effect the molecules are split and the ions are conveyed by the electrical charges along a definite path of conduction, which, in so dense a structure as dentine, provides no means of circulatory absorption of the dissociated salt, the medicamental effect, if produced at all, must be of a lasting nature. Chloride of zinc and silver nitrate as metallic salts in solution have long been known to have obtunding effects on sensitive dentine, but much of the good effects are lost in ordinary applications for the lack of penetration. With electrical application we are provided with just that which is lacking to obtain the desired effect.

Septic infection of the oral cavity is accounted by some authors to be the principal cause of facial neuralgia arising from fifth-nerve reflexes, and it can be readily conceived that constant afferent impulses directed to the nerve centres from the seat of such general irritation, accompanied by the general constitutional depression and lowering of the tone of the system by absorption of septic matter, would be the

cause of nerve excitability and even disease of nerve centres directly connected

But the sensitive condition of soft tissues in periodontal disease is not as frequently the irritant responsible for reflected pain as is the sensitive surface of the teeth themselves, which are liable to cause reflex pain from influences that do not affect the soft tissues, such as thermal changes, sweets, or sours.

In treating sensitive pyorrhea teeth a flat zinc electrode of large enough area to cover the whole surface of a mandibular incisor should be wrapped with cotton-wool which is saturated with 3 per cent. zinc chloride warmed to 99° Fahrenheit, the electrode should be firmly pressed to the surface of the tooth and the current turned on very gradually until felt by the patient; by keeping it steady it is often possible to use more current, the current should be turned off slowly after a few minutes and the operation repeated on another tooth. These teeth are very susceptible to shock from sudden alteration of the E. M. F. and great care is necessary in using the current. Periodontal and gum tissue can be treated at the same time by passing the point of the electrode under the gum; the number of treatments and the time occupied correspond with the method of treating septic periodontitis already described.

Neuralgic pain referred to in connection with periodontal disease is usually slight and transient, but occurs frequently and is the cause of much discomfort to the patient, who will complain of it. A more severe form of facial neuralgia which is probably developed from long standing and everlasting repetition of the slighter form is well known to the medical world. The sufferings of the patients in these cases are intense and the medical man is usually consulted. The electrical treatment of these cases has met with considerable success. The principle of counter-irritation is carried out with a continuous current applied with electrodes of large area and a current of considerable intensity. The active electrode is applied to the whole surface of one side of the face in close

contact with the skin, it is E-shaped, which leaves apertures for eye and mouth. The indifferent electrode, also of large area, is placed at the back of the neck. A current of 30 to 80 ma. is passed for half an hour at a time every day or every other day, diminishing the current as the neuralgic symptoms become less. Good results are claimed for this method of treatment when the neuralgia is of local origin. Leduc[1] has reported the successful use of salicylic and quinine ions introduced electrically by much the same technic as just described. The method is quite new but the results already obtained in severe trigeminal neuralgia should lead to its general use in these cases, especially when other forms of treatment have failed. Dr. R. W. Mackenna reported a case of immediate relief of neuralgia by the use of salicylic ions with a comparatively low current. He says: "I have had remarkable proof of the efficacy of the salicylic ion in the treatment of neuralgia following herpes. The patient had not slept for four nights because of the intense pain, but found relief after the ions from a 2 per cent. solution of salicylate of soda had been carried into the affected zone by a current of 7 to 11 ma. for thirty minutes. She was able to sleep immediately afterward, and when next seen had had no return of pain."

In cases of neuralgia of the trigeminus dependent on some form of peripheral irritation, where the nerve trunk in its passage through bony canals is not affected by disease of those parts or by pressure from tumors in its vicinity, a form of electrical treatment has been recommended by many which is not dependent on influence of ions introduced subcutaneously, but on the counter-irritation effect of a weak current applied to the painful area. By this method a continuous current of 3 to 5 ma. is passed for five to ten minutes with the anode of a surface area of about 6 sq. cm. applied to the points of emergence of the branches of the nerve, the cathode is attached over the upper cervical vertebræ and has an area of about 100 sq. cm. The electrodes must

[1] Archives d'Electricité Méd., July 25, 1904.

be firmly applied, care being taken to avoid interruptions in the circuit. The results of this form of treatment of facial neuralgia is sometimes very effective and most gratifying, relief being obtained by one daily treatment, and if pain recurs the application promptly relieves it.

Lewis Jones[1] says of trigeminal neuralgia, "In this condition, in particular, the salicylic ion has yielded most satisfactory results, and successful cases have been recorded by numerous writers." The application is made by placing a folded cloth pad over the whole area of the face, on this securely bandage the feet-covered electrode, the pad is moistened with a hot solution of sodium salicylate, 2 per cent. The indifferent electrode is placed upon the chest or under the shoulders. Care must be taken that all binding screws and conducting cords are securely fastened and in good condition. A current of 30 ma. or more is applied for half an hour, and repeated every second day for the first week and every third day after. The salicylic ion is an anion, it is therefore applied at the negative pole. The current should be turned on and off very gradually. Good results are so often reported from this method of treating trigeminal neuralgia, that it certainly should be tried in difficult cases, especially when other local treatment fails.

[1] Ionic Medication, p. 102.

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